OPERATIONAL READINESS MEASUREMENT: THE PHILOSOPHY AND THEORETICAL FORMULATION OF A VALUE-BASED QUANTITATIVE APPROACH

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OF A

VALUE-BASED QUANTITATIVE APPROACH

by

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ABSTRACT

A theoretical Unit Operational Readiness Index model is developed after presenting a discussion concerning the implications of military force readiness evaluation. The theoretical model is designed around subject measurement of defined military goals. The quantification of defined goals in the manner proposed suggests the possible use of factor analysis techniques which are discussed. Although the model has not been empirically tested, it endeavors to provide a conceptual visualization of unit operational readiness evaluation and argues for the benefits to be derived from comprehensive schemes of this general type.

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GLOSSARY OF SYMBOLS

ASW	Antisubmarine Warfare
a_{ji}	Factor analysis coefficients
b_j	Performance level for ELEMENT j
e_{ij}	Readiness ELEMENT (definition) j belonging to FACTOR i
F_i	Readiness FACTOR (definition) i
F_i^*	Optimum attainable scalar for FACTOR i
F_i'	Measured scalar in FACTOR i
HC	High Level Command
MC	Major Command
m_j	Minimum condition for ELEMENT j
OP.R.	Operational Readiness
p_{ji}	Distribution percentage for v_j among FACTORS i
$\vec{R}_{opt}^{(ASW)}$	OPERATIONAL READINESS INDEX for ASW SQUADRONS
${}_t\vec{R}_K^{(ASW)}$	OPERATIONAL READINESS POSTURE of $UC_K^{(ASW)}$ observed at time "t"
$R_{min}^{(ASW)}$	Minimum acceptable POSTURE level
TYPE "T"	A specific kind of military unit
UC	Unit Command
$UC_K^{(T)}$	K^{th} Unit Command of TYPE "T"
v_j	VALUE (weight) associated with ELEMENT j
$\bar{v}_{jK}$	Estimate of v_j given by K^{th} Unit Command
$\hat{\bar{v}}_j$	Average of $\bar{v}_{jK}$
V	Matrix of estimates $\bar{v}_{jK}$ (Lxn)
$\vec{v}_j$	A row vector of estimates from matrix V
$\vec{v}_j^*$	Factor analysis representation of $\vec{v}_j$

ACKNOWLEDGEMENTS

I have attempted to acknowledge all sources of inspiration and information, knowing full well this is not entirely possible since one's education and experience are in good measure a synthesis of the work of others. To them I am indebted.

Bearing this in mind, I extend sincere appreciation to Professor C. C. Torrance for his assistance in the formulation and philosophy of this paper; to Professor H. J. Larson, as a second reader, for his valuable assistance in editing the mathematical discussion of Chapter III; to Mrs. London for her cheerful assistance in the preparation of the manuscript; and to Mrs. Carol Dunsford for typing the final copy.

PREFACE

The problem of evaluating the preparedness of military units to engage in wartime operations has become a difficult and major one for the nation's military planners. The fact that great effort is being expended in readiness evaluation and will continue to be expended (as long as war is possible) is in itself indicative that a final "true" solution to the problem may never be reached in the sense that we are able to determine exactly what our national position is with regard to military readiness, now or in the future. Regardless of this fact, it is imperative that we continue the search for "better" methods of estimation. This thesis is dedicated to that end.

Concerning footnotes: Two types of footnotes are used in this paper. The first is a superscript number following a sentence; this refers to a page or pages from a reference source, which are listed at the end of each chapter. The second type is the traditional reference to the bottom of the page where amplifying information is given. These are marked by daggers (†).

INTRODUCTION

The nature of this thesis is theoretical in its approach to the problems of military force readiness evaluation. The purpose of the thesis is twofold. The first purpose is to draw attention to what continues to be an urgent need for increased capabilities in evaluation of military readiness posture. The second purpose is to develop/offer a method for analyzing readiness posture. In order to emphasize the need and set it in its proper perspective, an effort has been made to point out some of the background problems which generate the requirement for quick-reacting military forces. This has been done by examining briefly some of the problems encountered on the international political scene as mankind searches for a stable world at peace. Specific emphasis is placed upon the significance of the readiness evaluation problems brought by the nuclear age. In addition, the endeavor has attempted to focus on the severity of consequences of high level decision-making and its effect upon ultimate readiness posture.

The purpose and intent of this thesis will be served if: 1) a serious concern over the present methods of readiness evaluation is recognized, especially at lower echelon levels, and 2) motivation is provided for additional concentrated research and analysis in the critical aspects of military readiness posture evaluation and how it affects this nation's defense. Bearing these points in mind, the body of the thesis has been divided into three chapters which relate to the readiness evaluation problem in definite ways.

Chapter I summarizes military force readiness as a significant factor in this nation's attempt to seek a world at peace. Chapter II discusses some (not all) of the subtleties of the many complex problems involved in evaluating readiness of a combat-ready military force; no attempt is made to address specific problems or develop techniques to yield answers as each case, in any event, will have its own peculiarities and hence is emphemeral. In Chapter III, a detailed description is given of an Operational Readiness Index Model. This theoretical model is designed to provide a general basis from which a readiness evaluation scheme can be constructed for lower echelon military units. In doing this it is hoped that a framework will be provided which will permit insight into the magnitude of the various problems concerning readiness posture evaluation on the unit level. The intent of the model is specifically to reveal the salient features of readiness evaluation.

The following arguments, at the heart of readiness evaluation, are underlying considerations throughout the paper:

1. The most elaborate and sophisticated piece of weaponry designed is worth little, regardless of purchase cost, if not utilized properly and competently. The aspect of national defense perhaps most essential to our ultimate survival as a nation is the posture of the military forces.

2. The second argument concerns the gravity of the commitment that high level threat analysis places upon the nation. No matter how efficient and capable the forces in being are, with respect to military readiness posture, if the threat they are designed to counter has been (even to some qualitative extent) misinterpreted, then our readiness posture in these areas assures us nothing.

PROBLEM STATEMENT

Operational readiness, its evaluation, measurement, quantification, etc., is intrinsically vague. Present evaluation schemes have not in all cases achieved the desired goals. The problem dealt with in this paper is operational readiness measurement. The following questions were investigated in varying detail and scope concerning readiness measurement, its purpose and methods:

1. What are the fundamental purposes of readiness measurement?
2. What are the considerations surrounding military readiness measurement?
3. What does readiness measurement seek to determine?
4. What must readiness measurement schemes consider?
5. Are there general underlying principles or concepts present in any determination of military readiness--regardless of service branch, type unit, command structure, etc.?
6. What defines the concept?
7. Can it be effectively measured or quantified?
8. What constitutes the criteria involved in the determination of operational readiness?
9. Is there a "generalized" measure of effectiveness universally applicable to military units of all variety?
10. Can a meaningful theoretical structure (an ideal concept) be devised that would provide insight or assistance to military planners with respect to the establishment of operational readiness evaluation schemes?

CHAPTER I

CONSIDERATIONS SURROUNDING THE NEED FOR MILITARY FORCE READINESS EVALUATION

"Those who do not remember the Past
are condemned to relive it."

Santayana

MAN'S DILEMMA:

The Search for Peace in a World on the Brink of Total War

Chapter I endeavors to re-emphasize the "why" of military readiness. It is considered beneficial to set the stage properly before probing into the matters of readiness measurement.

Central to man's problem of government is the inability of nations to exercise self-discipline or regulation. Mankind has apparently failed to realize that collective international well-being is linked to individual national well-being. The impending tragedy of this age is that time may be too short to acquire this realization. If we are to achieve a world at peace, some form of concert of purpose among nations must be reached. The prevailing problem is the search for peace, but in these times it is a search for survival, the search for a means to avoid a head-on confrontation followed by international thermonuclear exchange.

Power on the International Scene

Political power has been described as essentially the ability to make one's influence felt, particularly influence of one nation upon another. The driving force behind sovereign nations is the desire for power. The problem is to find a satisfactory means of controlling and directing this drive for power. Traditionally, there have been (at least) two theoretical methods proposed as solutions. The first is through national self-control of power, i.e., self-regulation of national desires and actions. The second method takes the form of international regulations or international law in a normative legalistic sense. This entails a set of laws established by a legal body consisting of representatives of member nations and enforced by a policing agency supported by those various member nations. Both methods are influenced by world opinion and international morality.[1] Apparently, however, no means of enforcing either system of control is at hand on the international political scene today.† In short, neither of the methods spelled out appears to have much likelihood of success under present conditions.

As far as this nation is concerned at present, two facts are important. First, the United States is unequivocably the single most powerful nation on earth militarily and economically. Secondly, the United States is not so powerful that she may ignore the rest of the world.[2] Hence, we in the United States are in the position of being able to advance directly the cause of a permanent peace, and we must discover a means to do it with the assistance of the rest of the world's powers.

In the present "bi-polar world," the direction this nation's government has taken in an effort to find an overall solution to peace can be described by the concepts of deterrence, arms control and

†In this regard, we mean an agency in being, at all times capable of extracting discipline from even the most powerful single nation. The United Nations in its present form clearly does not fall into this category.

disarmament. We have approached the problem (mankind's dilemma) by endeavoring to manifest our national power in the form of deterrence, while at the same time advocating a retreat from the arms race, in the form of arms control and disarmament measures.

Deterrence

This nation has placed confidence in the concept of deterrence which, as we have practiced it in this age, is composed of two aspects. One is the determination of the nature of the threat to be deterred along with the creation of weapon systems and forces to counter that threat. The other aspect is concerned with the <u>operational readiness posture</u> of these military systems.

Prospects

Mankind's dilemma, its most urgent problem, is to establish a world system of nations at peace when faced with the possible alternative of world destruction if a solution is not reached. A key element of any workable solution will be for nations to realize that their well-being is linked to that of other nations. This nation, in a position of world leadership, has realized this fact and has attempted to forestall the holocaust of nuclear war by the techniques of deterrence. The prospect of mankind's reaching a world at peace before the commencement of a thermonuclear exchange is therefore dependent upon:

1. This nation's maintaining its desires for a world at peace and its willingness to exercise self-control; and

2. This nation's carefully pursuing its deterrence policy through strategic threat analysis and <u>military force readiness</u>.

NATIONAL SECURITY

> ...to be successful in the international system of this era, a nation must weld all of its national security policies into a coherent and fully synthesized body of doctrine. To pursue goals which are incompatible through strategies which are irreconcilable is to court disaster.[3]

Though this nation may seek a world of lasting peace, we cannot seek it at the cost of risking possible disaster. Since at present we concurrently seek a ready posture and an arms reduction--two seemingly incompatible objectives--the question is, how do we avoid courting disaster?

The ultimate objective of this thesis is to analyze and discuss a method (and the associated problems) of evaluating the readiness posture of alert and ready military units; but to obtain a proper perspective of the critical nature pertaining to the results of readiness evaluation, it is necessary to examine the political forces that have tended to generate the security requirement.

Modern history has demonstrated that regardless of the United States' ultimate goal as a nation, there are existing forces that can be safely controlled or diverted only by conducting our foreign policy from a position of political and military power.

Political Scene

World War II was a testing ground for three political-philosophical ideologies that all purported to have a solution for ultimately achieving a stable world (although the motivations and means of attaining that stable world were drastically different in each case!). One of these, ultranationalism, failed that test. The remaining two political ideologies, democracy and communism, emerged in a struggle that is yet to be resolved.

World communism appears to have within its ideological development acquired a doctrine that we as members of a democratic society may conceivably use to advantage. The "Doctrine of Inevitability," as it has been called, states that eventually, no matter how long it takes, the world will be a communist entity![4] The communists are apparently willing to wait to make their international moves. They have in their political philosophy an ingrained willingness to accept a setback today in the prospect of a future gain; as an example, one can cite the Cuban Missile Crisis of 1962. This fact may be enough to permit this nation to pursue a policy designed to await certain possible transformations within the communist system. If we are able to remain strong enough for long enough, then it is conceivable that a natural transformation of Soviet governments will permit Soviet leaders of different rationale to make re-evaluations of their objectives and ultimate goals.

There are two additional points to consider with respect to world totalitarian philosophies as exemplified by world communism. The points are pertinent in examining major political factors on the world scene that affect our national security and hence direct attention to the quality of our military defense, its systems and, particularly, its readiness.

1. The first point to discuss is the apparent inability of totalitarian states to perpetuate themselves in an identical form.[5] The problem of perpetuation can be accompanied by corruption from within, eventual rebellion, or gradual transformation by the successors as the previous leader's methods and concepts either fade away or are construed for convenience. The important point is that turmoil within totalitarian states during a power shift can be a critical period for any would-be

enemies of that state. Hence, no matter which political direction a powerful totalitarian regime turns to in a change of authority, a strong U.S. military deterrent force that maintains its continuity of position and posture will tend to have the effect of lessening the danger. (Although, quite obviously, there is no absolute guarantee of this!)

2. Totalitarian governments have the tendency to create and maintain state enemies. The reason for this stems from the need of the totalitarian to divert attention outside the nation. In essence, this is done by creating in the masses a fear of other nations. It is this fear and hysteria that are unleashed in the form of engagement in or support of aggressive wars of liberation and conquest.[6] We cite Mainland Communist China as an example of this fact. This emphasizes the need for the U.S. to maintain limited war capabilities.

Readiness Analysis

For the purpose of our analysis of military readiness, the point is clear that we desire a military system that consistently maintains a high level of readiness posture in its dual role as a deterrent force and a limited war suppressor. The nation's security under the present circumstances continues to need not only a force of sufficient size, but just as importantly, one that can react effectively and quickly. The question is, how do we ascertain the position of our units upon the "readiness scale"?

In this assessment we have 1) discussed elements of the international political scene that both cause alarm and create a cause for hope, but in either case the conclusions reached in the analysis have been that an alert, quick-reacting military readiness posture is demanded; and 2) discussed some of the aspects which lie behind our national concern over deterrence and limited war capabilities. These facts support the thesis that accurate readiness evaluation must continue to be improved as our national policy is based on the knowledge of it and our nation's success depends upon it. Lastly, we have implied that military readiness evaluation is critical inasmuch as it provides a gauge from which the nation can more effectively conduct its foreign affairs. It provides an evaluation "in time" of our capability to endure the cold war and the nuclear arms race as we seek a world atmosphere which will witness an actual reduction in the aggressiveness of world communist policy and orientation. By maintaining military readiness, we endeavor to obtain the time required to outlast the forces of totalitarianism.

MILITARY ROLE

The Dual Role

The primary role of the United States armed forces is the maintenance of a capable and competent deterrent force which can extract so severe a penalty for an initial nuclear attack that would-be aggressors conclude any such risk is entirely unprofitable.

The second role of our armed forces is to provide a capability for thwarting local wars of limited nature when these wars demonstrate that they are in direct conflict with the overall objectives of world peace and are a direct threat to this nation.†

Our concern is with these two military roles and the readiness evaluations that indicate the prospects of accomplishing the roles.

†The determination of what constitutes a "limited war in conflict with our interests and security" is another matter and will not be discussed here.

In this analysis the fact has emerged that our military forces can no longer envision their mission in the static sense. The rapid development of sophisticated weaponry and the fluidity of international politics, constantly shifting and re-orienting direction and alliance, have dictated that the United States armed forces execute their planning in a similar manner. By this we mean that there is a continuing requirement for looking at the nation's military force in "dynamic" terms. The hydrogen bomb is the weapon of our age but who is to say that it will always be so! "Dynamic thinking" in the military sense will permit us to have open minds with regard to strategies, tactics, techniques and the distribution of force to cover contingencies. Dynamic thinking will assist in arriving at the balance of systems--qualitatively and quantitatively--necessary to pursue the military's dual role as the instrument of deterrence and the instrument for minimizing the lethality of local wars. Dynamic thinking in threat analysis will ensure every possibility of arriving at conclusions that are not blocked by preconception, which in turn will tend to enhance overall readiness posture.

Deterrent System. The military role of deterrence is today the most critical. In the deterrent system, two points are germane:

1. Nuclear retaliation capability that approaches 100%. (This implies successful launch of the proper numbers of weapons that can penetrate any anti-ballistic missile systems and score the planned level of destruction.)

2. Quick reaction to aggressor-initiated nuclear exchange, i.e., instant retaliation. (This in turn implies a "high" level of military force readiness.)

Limited War System. The military's second role is to provide a limited war capability in order that "so-called" limited size conflicts do not become unlimited, i.e., militarily speaking, limited wars are waged to stop the spread of the aggression which precipitated them. This second role calls for a diversity of equipment and skills throughout every branch of service. The emphasis must be placed on a balanced force capable of exercising a maximum of strategic and tactical flexibility which is kept at the peak of readiness posture. The local war can be characterized by the following:

1. New types of weapon systems.
2. New types of combat organizations.
3. New machines to enhance mobility.
4. Superior systems of locating enemy positions.
5. High quality personnel completely trained in the new combat techniques.[7]

These points dictate the need for a readiness evaluation scheme of the highest capacity for posture measurement.

Men and Machines

Just as the Nation's security is served by the military forces so the military forces are served by men and machines. It is the proper choices of the numbers and types of men and machines that will have a direct bearing on our success, but it is even more important that these men and machines have been properly integrated. It is the efficiency with which the various components are brought into a harmoniously operating entity that is vital. In short, combat effectiveness is mandatory. We are asking for dedicated, professional militarists, men who are capable, competent and highly skilled.†

Factors of Readiness

The analysis conducted has shown these factors influencing military force readiness:

1. Accurate strategic threat analysis.
2. Instant readiness (as opposed to mobilization potential).
3. Combat effectiveness.
4. Professional character (the benefit of experience from career personnel).
5. Qualitative superiority (equipment types and unit organization).
6. Quantitative sufficiency (numbers and types).
7. Flexibility (strategic and tactical usage of units within systems forces).
8. Mobility (capability of wide deployment under a variety of circumstances).[9]

(Each item will normally enter an operational readiness posture evaluation scheme in some sense, if only implicitly.)

SUMMARY

Chapter I has discussed military force readiness in its relation to this nation's defense. The points discussed highlighted those aspects of the international scene with which the nation's military must contend,

†We note that the armed forces of the United States suffer much in readiness because of the high turnover of officers and enlisted personnel.[8]

viz., deterrence and limited war. Emphasis has been placed upon the fact that military force readiness is the _sine qua non_ of this nation's security in the nuclear age. The following considerations are pertinent to readiness evaluation:

1. _Threat analysis_, which is determined by the ramifications of events on the international political and military scene, will be the influencing factor upon ultimate readiness postures obtained.

2. _Weapon system analysis_, or cost estimating that determines choice among weapons and personnel requirements, is necessary for planning and economic reasons but will _not_ by itself determine a given readiness level.

3. The sophisticated machines and techniques of this era demand a sophisticated _dynamic system of readiness posture evaluation_. We should not permit the potential capability of systems and machines to be considered more important than the capabilities of the men who command them.

FIGURE 1.1 is a diagram depicting military force readiness evaluation with respect to discussion of Chapter I. The "influence lines" show dependence of the receiving block upon contents of the originating block. "Input lines" are deterministic in the sense that the receiving block is _forced_ into an action by the originating block. The "pickoff lines" indicate measurement either qualitatively of quantitatively.

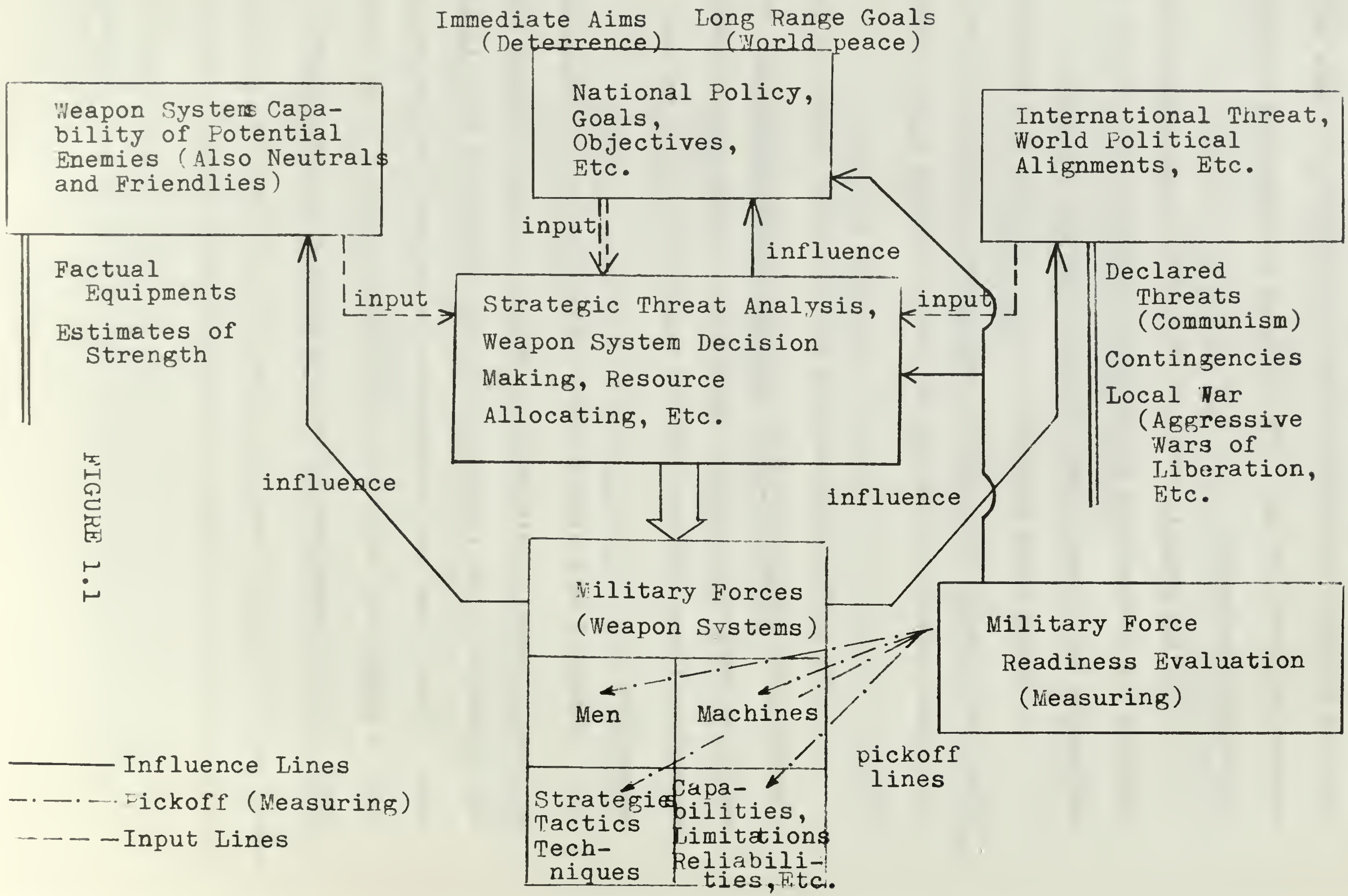
Immediate Aims
(Deterrence)
Long Range Goals
(World peace)
Weapon System Capability of Potential Enemies (Also Neutrals and Friendlies)
National Policy, Goals, Objectives, Etc.
International Threat, World Political Alignments, Etc.
Factual
Equipments
Estimates of
Strength
input
input
influence
input
Strategic Threat Analysis, Weapon System Decision Making, Resource Allocating, Etc.
Declared
Threats
(Communism)
Contingencies
Local War
(Aggressive
Wars of
Liberation,
Etc.
influence
influence
Military Forces
(Weapon Systems)
Men
Machines
Strategies
Tactics
Techniques
Capabilities,
Limitations
Reliabilities, Etc.
Military Force
Readiness Evaluation
(Measuring)
pickoff
lines
Influence Lines
Pickoff (Measuring)
Input Lines

FIGURE 1.1

CHAPTER I FOOTNOTES

[1]Hans J. Morganthau, _Politics Among Nations, The Struggle for Power and Peace_ (New York: Alfred A. Knopf, 1961), p. 23.

[2]_Ibid_.

[3]J. David Singer, _Deterrence, Arms Control and Disarmament, Toward a Synthesis in National Security Policy_ (Ohio State University, 1962), p. 239.

[4]William F. Thompson, "The Treatment of Subjective Factors in Threat Analysis" (Master's thesis, Naval Postgraduate School, 1961), p. 2.

[5]Z. K. Brezezinski and C. J. Friedrich, _Totalitarian Dictatorships and Autocracy_ (revised edition; Cambridge: Harvard University Press, 1965), p. 11.

[6]_Ibid_., p. 172.

[7]R. D. Challener and G. B. Turner (ed.), _National Security in the Nuclear Age: Basic Facts and Theories_ (New York: F. A. Praeger, Inc., 1960), p. 272.

[8]Hanson W. Baldwin, _The Great Arms Race: A Comparison of U.S. and Soviet Power Today_ (New York: F. A. Praeger, Inc., 1958), p. 74.

[9]_Ibid_., p. 96.

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CHAPTER II

MILITARY READINESS MEASUREMENT

"Science is Measurement"

From the Cowles
Commission Seal

The discussion developed in this chapter is directed at emphasizing certain aspects that surround military force readiness and posture measurement. None of the particular points addressed here are presented as new ideas by themselves. Rather, the objective is to emphasize their collective influence upon readiness posture. It is not meaningful to discuss or in any sense measure readiness posture (on any level) unless we know what we are attempting to measure, and more fundamentally, why we are measuring it.

Determination of the Nature and Extent of the Threat

The need for the vast military forces has created serious problems of management (in the sense of overall guidance and control). For our purposes, however, there is only one aspect of the complex management problem we wish to address and that is threat analysis. Our concern is with the high level decisions that result in the various defense plans and weapon systems programs.

These are the decisions which result in directing or orienting the military forces toward their objectives or missions. Similarly, we will find that threat analysis (for example, analysis of enemy tactics) conducted at the lower echelon levels when relating to readiness evaluation schemes will affect unit training objectives. The extent to which this analysis helps or hinders readiness posture is, of course, dependent upon the accuracy of the threat analysis. The point is that such threat analysis is critical as an input to any type of readiness measurement scheme.

Underlining Gaming Aspects. Strategic threat analysis involves a multitude of philosophical, political†, technological and economic factors, each of which enters specific analysis in varying degrees. In toto, threat analysis takes on the characteristics of classical game theory, where numerous participants, with various objectives, seek collectively or separately to secure their goals. Final estimates of enemy capabilities and potential threats are determined by considering the action an enemy is likely to take, but the situation is cyclic for his decisions and actions are based on what we do, etc.[1] These problems are extremely complicated at the strategic level and are difficult even at the unit level. They are nevertheless obviously investigated in detail to develop an insight to the problem as it exists. The point we emphasize is that, in a similar manner at lower echelon analysis of readiness evaluation schemes, the gaming aspects of threat analysis should provide insight to the development of new tactics, stimulate innovation in operational planning, and provide the units with the widest possible flexibility in pursuing their mission.

Underlying Philosophies. The treatment of threat analysis at higher levels would normally include as many ramifications of the pertinent political and ideological philosophies as necessary. At the lower level and in particular for unit readiness evaluation purposes, detailed attention should be given to the lesser philosophical aspects

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†"Political" includes its extension into the military arena.

as they pertain to enemy tactics and habit patterns concerning enemy problem solving, e.g., the Oriental proclivity for human sacrifice as a substitute for technological skill.

The Scientific Approach. Estimating and establishing the enemy threat is the starting point from which additional command or unit problem areas are often discovered. The value of a scientific approach to threat estimations by both high and low level staffs should be obvious. Particular attention should be given to this concept by low level staffs developing readiness measurement schemes where the tendencies to "approximate" or "omit" for convenience may be strong.

Sound analysis should include, in general:

1. Determining purposes or objectives.
2. Establishing measures of effectiveness.
3. Obtaining and analyzing data.
4. Determining solutions.
5. Evaluating and criticizing results.
6. Correcting deficiencies.[2]

The Commitment of Resources

The national resources invested in defense demand that every attention be given to proper utilization of manpower and materials in order to avoid waste.[3] A partial solution can be provided by augmented readiness evaluation schemes which properly direct unit objectives and missions, thereby helping to reduce waste, e.g., establishing operational maximum expenditures as well as minimums in appropriate situations. Readiness measurement schemes should be capable of assisting in the proper utilization of allocated resources.

Military Posture: Use of Men and Machines

The Need to Measure Readiness Posture Effectively. Chapter I stated the necessity and purposes of the military forces. If their objectives and purposes are to be obtained and fulfilled, the most efficient way to do so is by establishing some method or scheme that allows reoccurring comparisons between performance and goals. By comparison of given goals with force posture or performance, necessary corrective action can be taken to upgrade the forces to the desired readiness status which has been previously specified by "high level" threat analysis.

Results Desired from Readiness Evaluation. Certain results should be obtainable from military readiness evaluation schemes. These are fundamentally the following:

1. Point evaluations, which depict the posture of a unit or force at a certain specified period.

2. Trend analysis, which permits a comparative analysis of force stature over a specified duration. (This may entail some type of histogram, which records pertinent readiness information to predict rates of changes, general posture development in critical areas, etc.)

3. Feedback, which essentially entails a flow of information from units or forces back through the readiness analyzing staff to the strategic threat analysis and planning levels.

Dynamic Measurement. In Chapter I, emphasis was directed toward the concept of "dynamic thinking," which amounts to maintaining a constant vigil on the evolution of military matters and indeed on those fundamental political domains behind the military. An extension of this concept should be applied to military posture evaluation schemes. Generally, "dynamic measurement" as applied to evaluation schemes entails systematic updating of the scheme, periodic re-evaluation of underlying concepts, a general flow of data and information in the form of suggestions for improvement, correction, or re-direction of effort for units concerned.

SUMMARY

Chapter II has briefly discussed some of the important aspects of the function of a military force which any readiness evaluation scheme must attempt to measure, viz., 1) capability to counter the threat; 2) expenditure of allocated resources; and 3) use of men and machines. The purpose has been to direct attention to those problems as they relate to readiness evaluation schemes, not to solve them or provide methods for solving them as the specifics in any case will dictate the techniques.

CHAPTER II FOOTNOTES

[1]T. C. Schelling, "Assumptions About Enemy Behavior," Chapter 10, Analysis for Military Decisions, E. S. Quade, editor (RAND Corporation, R-387-PR, November 1964), p. 199.

[2]William F. Thompson, "The Treatment of Subjective Factors in Threat Analysis" (Master's thesis, Naval Postgraduate School, Monterey, California, 1961), p. 21.

[3]Charles J. Hitch and Roland N. McKean, The Economics of Defense in the Nuclear Age (New York: Atheneum, 1965), pp. 1-2, 23-43.

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CHAPTER III

OPERATIONAL READINESS INDEX

> We are looking for people with imaginative and probing minds in order to stimulate the prophetic side of the planning business. They must be skilled observers and objective analysts. They must overcome service bias, military bias, and every other kind of bias. They must respond intellectually, not emotionally, to the threat of change and the hazards of their profession.
>
> The Honorable Eugene M. Zuckert
> Secretary of the Air Force[1]

SECTION 1

1.1. BACKGROUND

Chapter I discussed briefly that the world environment imposes definite requirements upon the U.S. for maintaining a versatile and effective military force. The rapidly changing developments indicate the requirement for readiness evaluation schemes that produce reasonably reliable estimates of readiness posture on a continuing basis. Chapter II discussed some of the problems regarding measurement of readiness. Readiness measurement information is desired for reoccurring comparisons of current military postures versus optimum readiness levels. This is done so that adequate corrective actions can be taken by operational commanders to assure unit progress toward the desired readiness level.

The problems involved with operational readiness evaluation are multiple and complex. Even the lowest level of readiness evaluation may cause problems for the analyst if proper care is not taken in identifying the functional qualities to be measured in a military unit as those qualities relate to the assigned mission. It is necessary to determine the qualitative and quantitative aspects of the unit's mission prior to determining which of the unit's functional qualities need measuring, e.g., one identifies what the target types are likely to be prior to deciding the importance of practicing some weapon tactic over another! Inherent subjective factors are imbedded within the evaluation of military force posture. Subjective factors emerge primarily as "value judgments" concerning decisions, estimations and the importance (merit) of specific events. Subjectivity is present in the very first phases of strategic threat analysis and remains as a consideration throughout the analysis of the military system to the final evaluation scheme.

1.2 OBJECTIVE

The objective of Chapter III is to develop a framework and theoretical model for lower echelon operational readiness evaluation. "Lower echelon" is defined to pertain to the more common and numerous types of military units. (Examples are the Air Force and Navy aircraft squadrons, Army and Marine Corps regiments, battalions, etc.) In general, "lower echelon" pertains specifically to those units of the military forces that exist at lower organizational levels. (Throughout Chapter III a Navy ASW squadron will be used as an illustrative vehicle. No particular type aircraft is to be inferred. The examples given are not to be construed as results of an analysis but merely as illustrations of notions involved. This caveat cannot be too strongly emphasized. The reader is encouraged to consider conditions similar to his own experience.)

For the purpose of illustration in this chapter, we define a "generalized command structure," consisting of three levels.† The three levels are 1) High Level Command (denoted HC), a command having the responsibility of specifying "broad mission objectives" to subordinates, e.g., high level strategic threat analysis is conducted at this level; 2) Major Command (denoted MC), a command having "operational" or "TYPE" control over lower echelon subordinate units. MC will have various areas of responsibility, e.g., (pertaining to Naval aircraft squadrons) MC will perhaps embrace multi-TYPE aircraft in multi-PURPOSE roles, i.e., ASW (Anti-Submarine Warfare), VF (Fighter), VA (Attack), VR (Transport), Helicopter, AIRGROUP, WING, etc.; 3) Lower Echelon Unit Command of TYPE "T", the command for which the Index is developed (the "K^{th}" Unit Command of TYPE "T" is denoted $UC_K^{(T)}$, where there are "n_T" Unit Commands of TYPE "T"; $K=1,\ldots,n_T$).

The importance of the definition is reflected in that emphasis is placed upon the relationship within the command structure and how each of the command levels can influence operational readiness. The $UC_K^{(T)}$ has control over a limited set of functions (operations, etc.) which are essentially a subset of those held in the MC. MC is controlled in its broader mission by the direction of HC.

The mission of MC is to maintain an operationally-ready combat force so that national "victory" in combat can be achieved.†† In order

†The clear-cut distinctions between levels of command, and for that matter between the staff analysts and decision makers, that are assumed in this paper, obviously, do not necessarily exist in the military force structure in the same exact sense.

††"Victory" has taken on different meaning since the advent of the thermonuclear weapon. The victor may have little more left after war than the vanquished.

to carry out this mission, the MC has to insure itself that the Unit Commands attached are at all times ready to carry out wartime combat missions. Just as $UC_K^{(T)}$ is limited in its alternatives to carry out its mission (UC has only its allotted "men and machines"), so also is MC limited in the courses of action (alternatives) available to carry out its broader mission (MC has only the various assigned Unit Commands). In effect, HC determines the entire course of events. It is assumed that the force levels, numbers and types of men and machines, etc., have been specified for MC (and hence, $UC_K^{(T)}$) by results of HC strategic threat analysis. It becomes MC's duty to carry out its assigned mission within the constraints imposed by HC. Heuristically, in consideration of its mission, MC maximizes expected success of the mission subject to the constraints imposed by HC.

In the typical case considered here, there will be numerous UC's, all with identical or similar missions, functioning with similar weapon systems, equipment, etc.

Since there exists (throughout the military forces) a variety of definitions of operational readiness, it shall be defined here to provide agreement within the context of this theoretical approach (model) to readiness measurement.

Define OPERATIONAL READINESS:

OP.R. $\equiv$ The condition or status of any military unit (or force) with regard to its capability or capacity to carry out the duly assigned operational mission (and/or objectives) and as such is broadly considered a function of that mission. OPERATIONAL READINESS describes, in an overall sense, the capability (capacity) for a unit to carry out its mission, though that mission may consist of several distinct parts.

(It is to be noted that, in general, Unit missions are defined in broad terms.) Readiness is a state of being and as such implies that a transitional process exists in that readiness at a given period may or may not be identical with that of a previous or subsequent period.

As a result of the above definition the term "POSTURE" is apropos in that it pertains to a particular "state of readiness" at a point in time.

1.3. QUANTIFICATION: AN INDEX OF READINESS POSTURE

The objective of the Operational Readiness Index is to quantify Unit posture. A specific number or set of numbers compactly describing military force posture is considered useful.

Chapter II stated the desired results of readiness evaluation. Quantification of posture can directly assist commanders and planners in pursuing assigned missions. Trends can be observed on Unit development. An evaluation scheme properly devised could observe problem patterns which are common among Units as they develop, e.g., personnel qualification problems may imply problems in training techniques, schooling, or even personnel retention. In the optimum state an evaluation scheme gives this sort of results plus direct comparisons among Units of the same TYPE.

The ranking of Units for competitive purposes is a natural result of a quantified readiness evaluation scheme and could give judges (commanders) sufficient data to decide winners of various awards, e.g., safety and combat efficiency (E) awards.

1.4. SUMMARY DESCRIPTION OF THE INDEX TO BE DEVELOPED

The purposes, desirability and objectives of readiness posture evaluation have previously been elucidated. A brief description of the Operational Readiness Index follows.

The Operational Readiness Index model envisions an Operations Analysis staff analyzing the "HC-MC-UC" relationship for the particular "Unit TYPE" that the Index model is being constructed. Thorough staff research is directed toward the various aspects of the MC's mission or objective and the UC role in supporting that mission or objective. Quantitative and qualitative aspects are examined in detail by the analyzing staff in order to develop fully the orientation of the UC mission. After complete analysis of the MC mission, attention can then be directed toward the UC, as its mission is, by this stage, coordinated with that of the MC.

1.4.A. READINESS FACTORS. With the UC mission clearly defined, the next "objective" in OP.R. Index development is to obtain the FACTORS of the UC that describe its operational readiness capability.†

Define FACTOR:

$F_i \equiv$ A basic or fundamental "function" (or operation) that significantly influences (reflects) the Unit Command's performance with respect to operational readiness. The subscript "i" sequences the FACTORS pertaining to $UC_K^{(T)}$.

†Though the next "objective" for the Index is obtaining FACTORS, this may, in given circumstances, be the end result of several major intermediate steps. This fact will be fully discussed at a later stage in Section 2.2 after an illustration has been given. FACTORS are defined at this stage because they will ultimately be the means of compactly expressing information concerning readiness posture.

$F_i \in \mathcal{F}$, where $\mathcal{F}$ is the universal set of all FACTORS that can significantly influence (reflect) operational readiness.

Examples of FACTORS (for a Navy ASW squadron) might be: F_1: Squadron Operations; F_2: Aircraft Maintenance; F_3: Squadron Personnel. FACTORS consist of ELEMENTS.

1.4.B. READINESS ELEMENTS. FACTORS are operationally described by ELEMENTS, i.e., the occurrence (or existence) of an ELEMENT "explains," to "some" extent, the capability (characteristics) of a FACTOR.

Define ELEMENT:

$e_{ij} \equiv$ The objectives or goals assigned to or defined for $UC_K^{(T)}$; they may take the form of a requirement on $UC_K^{(T)}$ that must be accomplished during a given time period or they may be qualification levels that must be maintained during a given time period. For e_{ij}, the subscript "i" associates the ELEMENT with the FACTOR F_i and the letter "j" subscripts the ELEMENTS belonging to a FACTOR (F_i), but "j" does not necessarily run sequentially, e.g., one may have e_{11}, e_{16}, e_{19} versus e_{11}, e_{12}, e_{13}, etc.

It is to be noted that it may not always be possible for a Unit Command to completely accomplish (or comply with) some particular goal (e_{ij}) during any one given time period due to various external circumstances that may develop. Note also that ELEMENTS form sets and are not considered a matrix. In some discussions in the literature of military readiness the term "indicators" is used in the same context as ELEMENTS.

As each ELEMENT may (not a necessary condition) describe capability in one or more FACTORS, a symbolic notation may be used, but before defining the notation an example is called for. Let e_{i8} be an ELEMENT defined as: $e_{i8} \equiv X$ number of ASW flight hours required to be flown by a Navy ASW squadron per month. It seems intuitively clear that e_{i8} should reflect capability in at least the two FACTORS (previously given for the ASW squadron) $F_1 \equiv$ Squadron Operations and $F_2 \equiv$ Aircraft Maintenance. Then in this case i=1 and i=2; therefore, $e_{18}=e_{28}$. The results of this example can be generalized by a modified form of set notation given symbolically by $(F_i:e_{ij})$ where the i and j are the same as given above. The ELEMENTS can form overlapping sets (but this is not a necessary condition).

FIGURE 3.1 should clarify these notions of ELEMENTS. $e_{ij} \in \xi$ where ξ is the universal set of all "L" ELEMENTS which define objectives or goals. Examples of ELEMENTS (pertaining to a Navy ASW squadron) might be: Number of pilots qualified in ASW tactics; Navigation and instrument hours per month per pilot; Number of ASW weapon exercises conducted per month per flight crew; etc.

As an illustrative example of the fundamental notions of FACTORS and ELEMENTS, consider the following:

Let $F_1 \equiv$ ASW squadron operations capability; $e_{11} = X$ number of pilots qualified in ASW tactics; $e_{12} = Y$ number of ASW Weapon Exercises conducted per month per flight crew; $e_{14} = Z$ number of required navigation/instrument hours per month per pilot. In this example one could specify (employing the notation above) that $(F_1:e_{11}, e_{12}, e_{14})$ gives some "reflection" of ASW squadron operations capability. Referring to the definition of an ELEMENT e_{ij} it can be seen that e_{11} is the definition of a qualification level that is to be maintained. As pilots are detached and new ones arrive for duty, the ASW squadron's capability

ELEMENTS

$\mathcal{F}$ \ $\mathcal{E}$	e_{i1}	e_{i2}	$e_{i3} \cdots\cdots$	$e_{ij} \cdots\cdots$	e_{iL}
F_1	e_{11}		e_{13}		
F_2	e_{21}	e_{22}	e_{23}		
.					
.					
F_i	e_{i1}		e_{i3}	e_{ij}	e_{iL}
.					
.					
F_r			e_{r3}	e_{rj}	
VALUE of e_{ij}	v_1	v_2	$v_3 \cdots\cdots$	$v_j \cdots\cdots$	v_L

FACTORS

L: the total number of all ELEMENTS

r: the total number of all FACTORS

FIGURE 3.1

An arbitrary example of FACTORS being described by sets of ELEMENTS. A particular ELEMENT may appear in different sets. This is not meant to imply a matrix, rather a diagram of "sets."

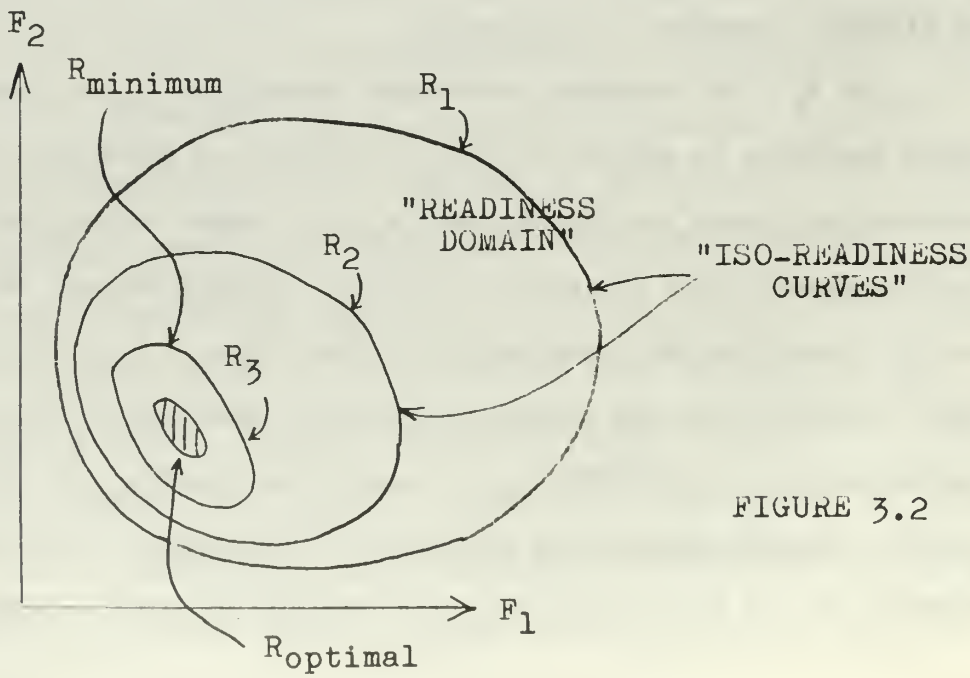


FIGURE 3.2

to maintain this defined level (e_{11}) will fluctuate. Similarly, e_{12} and e_{14} define goals assigned to the squadron which they may or may not be able to achieve during the allotted time period for various external considerations over which the squadron has no control. Whether or not a squadron has control over the circumstances surrounding the accomplishment of an ELEMENT is of no consequence to the Operational Readiness Index. We are explicitly interested in "measuring" the operational readiness posture of the Unit Commands. Of course, it will be of the gravest concern to the Major Command why the Unit Commands are unable to comply with (or accomplish) the defined requirements. The ramifications of the events surrounding unsatisfactory performance would, normally, as a consequence, reveal what external considerations or circumstances have prevented the Unit Command from exhibiting "satisfactory" performance.

One final note concerning the notation of the ELEMENTS. Although the subscript "i" will be carried forward in Section 1 to represent the fact that an ELEMENT may belong to more than one FACTOR, the "i" does not imply different ELEMENTS. ELEMENTS are indexed by the subscript "j" alone.

1.4.C. VALUATION. As the e_{ij} are definitions of objectives, goals or levels that $UC_K^{(T)}$ attempts to achieve or maintain (as appropriate) they should lend themselves to exact numerical quantification (as in the examples given in 1.4.B.). Let us assume that "somehow" the e_{ij} can be assigned values (weights)† according to their importance in F_i.

†Since a variety of definitions exists in the literature of Decision Theory and Utility Theory regarding weights, values, etc., we choose interchangeably to describe the "value" of an ELEMENT successfully accomplished as having a specified "weight."

It is only reasonable and logical to assume that there will be varying degrees of importance among the ELEMENTS. Some e_{ij} will be more important with respect to OP.R. than others and hence will have higher value (greater weight). In the second example of Section 1.4.B., let us assume that we are able to determine the values (weights) that are associated with e_{11}, e_{12}, e_{14} if they are totally satisfied, e.g., let "n" be the numerical value awarded to the squadron (for e_{11}) if there were X number of pilots qualified in ASW tactics as required, and similarly, values associated with e_{12} and e_{14}. In short, once definitions have been established concerning the e_{ij}, the attention of the analysts can be directed toward determining the "values" for ELEMENTS. Valuation will be discussed further in Section 2.4 where reference to Appendix I will be made. Before providing an illustration of the Operational Readiness Index a definition of the "value" for e_{ij} will be given.

Define VALUE of an ELEMENT:

v_j ≡ The numerical weight awarded to the Unit Command ($UC_K^{(T)}$) for totally (100%) successful accomplishment of a defined ELEMENT e_{ij} during the time period allotted. The subscript "j" corresponds.

The definition explicitly omits the subscript "i" because it is an ultimate objective to "divide" the VALUE (v_j) awarded for successfully accomplishing e_{ij}, so that v_j is distributed among the various FACTORS F_i to which e_{ij} belongs. Specifically, the definition has not in itself prescribed the method in which the VALUES (v_j) will be distributed among the FACTORS. This will be discussed in detail at a later stage. Referring to FIGURE 3.1, v_j's corresponding to e_{ij}'s are depicted along the bottom of the figure.

1.4.D. ILLUSTRATION. Prior to giving an illustration of the Index model of this paper it will be meaningful to describe its underlying notion. In FIGURE 3.2 is given a plot of two dimensions F_1 and F_2 (FACTORS). These are coordinate axes for the operational readiness "domain" as shown. The figure is topographical in the sense that F_1 and F_2 are similar to coordinates of a military map and the terrain (readiness) levels are given isometrically. As one proceeds to higher levels (R_1 to R_2, etc.) increased operational readiness is reached. The "optimum condition" is shown at the highest level. In order to measure (locate) our position in the readiness domain it is necessary to devise "some satisfactory method" for determining (approximating) the reference system involved. We seek (at least in theory) some method of obtaining information concerning the F's as they will indicate our coordinates (location) in the readiness domain. An optimal readiness state is shown as a subset of the readiness domain "$R_{optimal}$." Additionally, a minimum acceptable condition is shown as "$R_{minimum}$." These are the general underlying notions of this particular readiness evaluation scheme.

At this point we have sufficient notation and definitions to discuss the fundamental concept of the Operational Readiness Index. We do this at an early stage so that subsequent discussion of the Index scheme can be considered in light of this heuristic illustration.

Let us assume for purposes of a specific illustration (of reduced scope) that the important "functions" (FACTORS) pertaining to operational readiness for a Navy ASW squadron ($UC_K^{(ASW)}$; $K=1,\ldots,n_{ASW}$ (hereafter dropping the ASW subscript)) are specified as F_1, F_2 and F_3 where:

$F_1 \equiv$ OPERATIONS (OPS) e_{11}=No. Pilots Qualified in ASW Tactics

e_{12}=Weapon Exercises Conducted

e_{15}=Crews Qualified in ASW

$F_2 \equiv$ MAINTENANCE (MNT) e_{23}=Average A/C Availability

e_{24}=Average A/C Mission Aborts

e_{26}=Mech/Tech Qualified for A/C Maint.

$F_3 \equiv$ PERSONNEL (PERS) e_{35}=Crews Qualified in ASW

e_{36}=Mech/Tech Qualified for A/C Maint.

Therefore, (using the previous notation) the following sets are obtained: $(F_1: e_{11}, e_{12}, e_{15})$, $(F_2: e_{23}, e_{24}, e_{26})$, and $(F_3: e_{35}, e_{36})$. In this illustration (arbitrary), the fifth and sixth ELEMENTS each influence two FACTORS. One observes that, in this case, some part (percent) of the VALUE v_5 would logically be awarded to F_1 and F_3. Each "function" of the squadron has defined a FACTOR which influences operational readiness and, therefore, if a measurement can be taken (over a given time period) on the FACTORS, it will reflect the squadron's operational readiness during that period.

The Operational Readiness Index is developed from the following argument. To discuss OP.R., as defined in Section 1.2, one must look at the capability of the ASW squadron ($UC_K^{(ASW)}$) to prosecute the ASW mission of the Fleet Commander (MC). The implication is that the ASW squadron must be highly proficient in the utilization of men and equipment. Now, if we form a triple of the FACTORS, (F_1, F_2, F_3), and assume that we are able to measure this triple during a given time period we would obtain a "measured (numerical) triple" (F_1', F_2', F_3'). We will call (F_1, F_2, F_3) a defining triple while the primed F's will "measured quantities." (F_1', F_2', F_3') will "reflect" the ASW squadron's capability to prosecute the Fleet Commander's ASW mission (and hence its own) as long as it approaches or exceeds some prescribed level. Call this prescribed level (starred F's) the "attainable triple" (F_1^*, F_2^*, F_3^*), i.e., it is an optimum state for each FACTOR. We seek to define the Operational Readiness Index in terms of the prescribed level and eventually compare (F_1', F_2', F_3') to it using suitable criteria (that will be suggested at a later stage in Section 2.6.C) to determine if the squadron is OPERATIONALLY READY. This is in keeping with the discussion of Chapter II.

If the FACTORS can be <u>assumed</u> to represent (essentially) independent functions of the squadron, then one can interpret them on a geometric basis, considering each FACTOR as an axis in space. Specifically, in the ASW squadron example the "defining" triple (F_1, F_2, F_3) can be considered as defining a three-dimensional FACTOR (F_i) space, i.e., they define the axes of the space. (In the general case $(F_1,\ldots,F_r)$ defines an r-space.)

We may now state that the triples referred to above as (F_1', F_2', F_3') and (F_1^*, F_2^*, F_3^*) are <u>scalar</u> triples that are measurable; the former is the squadron's readiness posture reported at the end of a reporting period while the latter is an optimum readiness state. These scalar triples define vectors in the context of a three-dimensional space (as above). Therefore, define

$\vec{R}_{opt}^{(ASW)}$ ≡ The <u>OPERATIONAL READINESS INDEX</u> for the ASW squadron $(UC_K^{(ASW)})$, an optimum condition.

$$\vec{R}_{opt}^{(ASW)} = (F_1^*, F_2^*, F_3^*)$$

(The arrow over the "R" indicates a vector in a commonly used notation.)

Additionally, define

$_t\vec{R}_K^{(ASW)}$ ≡ The OPERATIONAL READINESS POSTURE OF $UC_K^{(ASW)}$ at time "t" (the time at which the READINESS REPORT is made to the Major Command).

$$_t\vec{R}_K^{(ASW)} = (F_1', F_2', F_3')$$

If the F_i can be assumed independent then from commonly used vector notation we may consider the defining triple (F_1, F_2, F_3) as defining an orthogonal three-space.

The methods for obtaining the scalar quantities (F_i' and F_i*) will be developed at a later stage (Section 2.6); it should suffice for now to state that the scalars will be a mathematical function of the v_j (which were defined in Section 1.4.C).

From vector algebra, a vector may be represented by a scalar multiplied times a "unit vector" that orients direction. Also any vector may be represented by a linear sum of scalars multiplied times unit length "dimension" vectors. Let $\hat{f}_i$ be a unit length dimension vector on the "i^{th}" orthogonal axis of an r-space (where the circumflex denotes "unit" length). By analogy and in the specific illustration concerning the ASW squadron, the OPERATIONAL READINESS POSTURE of the squadron at time "t" can then be given as,

$$_t\vec{R}_K^{(ASW)} = F_1'\hat{f}_1 + F_2'\hat{f}_2 + F_3'\hat{f}_3$$ (where the F_i' are measured in FACTOR "i").

$$= \sum_{i=1}^{3} F_i'\hat{f}_i$$ (a vector sum).

And similarly, the <u>ASW</u> <u>OP.R</u>. <u>INDEX</u> (in the case r=3) is given by,

$$\vec{R}^{(ASW)}_{opt} = \sum_{i=1}^{3} F_i{}^*\hat{f}_i$$

(where the $F_i{}^*$ are the optimum scalar quantities that each squadron attempts to achieve).

To determine whether or not the ASW squadron is OPERATIONALLY READY at the time period "t" one compares the squadron's <u>POSTURE</u> ${}_t\vec{R}^{(ASW)}_K$ to the OPERATIONAL READINESS INDEX $\vec{R}^{(ASW)}_{opt.}$. As the defined optimum readiness condition (state) of a military unit may or may not be obtainable during a time period "Δt" for which the unit's posture is to be assessed, yet the unit still performs to be an acceptable level, it is necessary to define a minimum acceptable <u>POSTURE</u> <u>level</u>. To do this we can employ a symbolic notation of a vector function. If "h" is a vector function, then one can define the <u>minimum</u> <u>acceptable</u> <u>POSTURE</u> <u>level</u> for the Unit Commands in terms of the OP.R. Index

$$R^{(ASW)}_{min} = h(\vec{R}^{(ASW)}_{opt})$$

Clearly, $R^{(ASW)}_{min}$ may be a scalar, vector, set of vectors, cone, surface, etc., depending upon the function "h". (As an arbitrary example of a vector function, "h" could be the function that directs all scalar coefficients of the $\hat{f}_i$ defining $\vec{R}^{(ASW)}_{opt}$ to be reduced by 25%; in this case $R^{(ASW)}_{min}$ is a vector.) In a similar manner one may define a vector function "g" for ${}_t\vec{R}^{(ASW)}_K$ that permits comparison of $\vec{R}^{(ASW)}_{opt}$ and ${}_t\vec{R}^{(ASW)}_K$ in an appropriate manner. For example, "g" could permit comparison of scalars, or "g" might permit one to establish whether the vector ${}_t\vec{R}^{(ASW)}_K$ lies within the volume of a cone or some other surface defined by $R^{(ASW)}_{min}$. The two functions "h" and "g" are vector functions which define the appropriate comparisons of unit POSTURE with the INDEX. Then if

$g({}_t\vec{R}_K^{(ASW)})$ satisfies all conditions defined by $h(\vec{R}_{opt}^{(ASW)})$, $UC_K^{(ASW)}$ is OPERATIONALLY READY

and if

$g({}_t\vec{R}_K^{ASW)})$ does not satisfy all conditions defined by $h(\vec{R}_{opt}^{(ASW)})$, $UC_K^{(ASW)}$ is NOT READY.

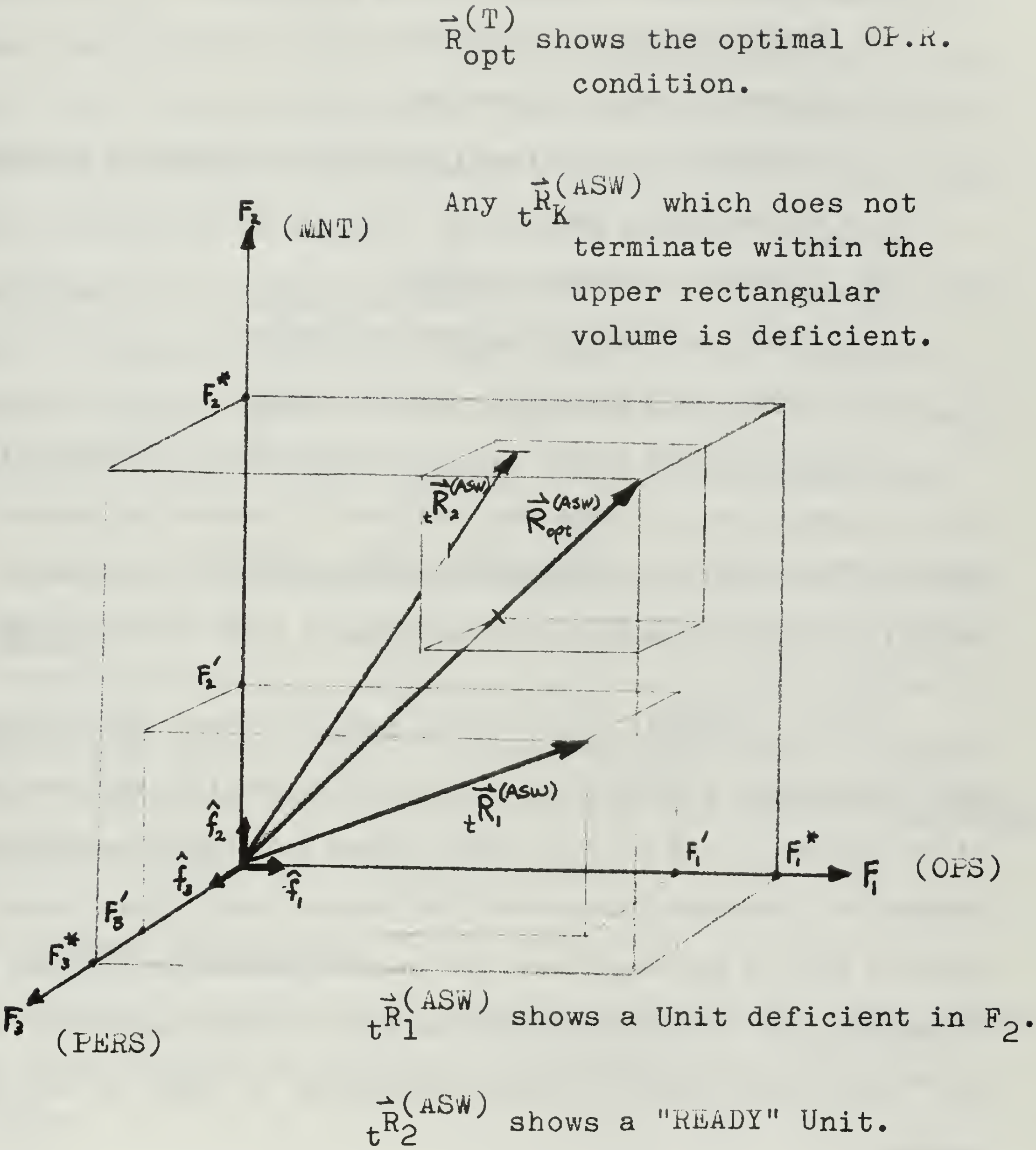
FIGURE 3.3 depicts the notions of this section and gives an $R_{min}^{(ASW)}$ condition which is a rectangular volume defined on $\vec{R}_{opt}^{(ASW)}$. $g({}_t\vec{R}_K^{(ASW)})$ states that ${}_t\vec{R}_K^{(ASW)}$ must be a vector with origin at (0,0,0) which terminates within the upper rectangular volume, if $UC_K^{(ASW)}$ is to be classified READY.

The objective of the foregoing discussion and illustration has been to describe heuristically the fundamental concept of the OP.R Index so that the following discussion of the analysis which surrounds Index development will be more meaningful.

1.5. THE MILITARY SYSTEM AS AN ENTITY: COMMANDS-UNITS

1.5.A. ANALYSIS OF SYSTEMS. The first step toward development of the OP.R. Index consists of a thorough and detailed analysis of the military system involved. The staff analysts will need information concerning:

1. Chain of command (and administration procedures)
2. Organizational structure (MC with respect to UC)
3. Missions (objectives)
4. Communications characteristics



Plotted $\vec{R}$ values for successive time periods "Δt" can exhibit trends in each FACTOR F_1, F_2, and F_3.

Note: In general, the three coordinates F_1*, F_2*, and F_3* need not be equal.

FIGURE 3.3

Dimensional Visualization of the OPERATIONAL READINESS INDEX, $\vec{R}^{(T)}_{opt}$

5. Inter-unit relationships
6. Weapon system (ordnance) characteristics
7. Operation-planning procedures
8. Resource (funds) allocations
9. Information (data) flow (networks); intelligence procedures within the system
10. Personnel training procedures
11. Maintenance-supply-logistics procedures
12. Others (as pertinent in specific cases)

If the system is complex, it may be desirable to develop diagrams for 1) organization, 2) communications, and 3) command and control features, utilizing the techniques of cybernetics and organization analysis. This in itself implies developing a model of the system.

1.5.B. FEEDBACK. Since the MC desires to know when discrepancies exist between the posture of the units and the desired readiness levels, it is imperative that the OP.R. Index scheme incorporate mechanisms for feedback of information concerning the mission, goals, objectives, etc. Implicit here is the requirement for analysts developing an Index to incorporate self-correcting procedures into the Index documentation that will facilitate corrective feedback concerning the Index as well as unit posture.

1. Command and Control. Every technique available should be utilized to establish properly a command and control relationship from MC through the OP.R. Index to the UC. However, the objective is to orient properly the Unit Command's operational endeavors, not to reduce (minimize or degrade) the responsibility and authority of unit commanding officers and subordinates in any sense.

2. Thinking System. The Index should enhance the military organization by stimulating a consciousness within unit personnel to regard the system as a whole. Conscious learning can be realized when units begin to practice innovation. We desire a state where constant improvement is sought as Unit Command personnel seek to converge their Index rating into the optimal. By devising a scheme of periodic comparisons with a defined optimum we introduce self-competition. This helps to avoid such pitfalls as faulty direction, poor management, improper planning, failure to investigate new methods, etc. In short, we desire to inject "dynamic thinking" into the Unit Command level.

1.5.C. READINESS INDEX CONTRIBUTIONS. A fully augmented Index scheme developed under the auspices of HC and MC with support from the UC's should both enhance readiness evaluation and provide stimulus for innovation as increasingly superior performance is sought. The Index scheme is envisioned as being an integral part of a system that continues to define objectives and enhance performance.

1.6. SUMMARY OF SECTION 1

Before proceeding to the detailed analysis of OP.R. Index development it is necessary to consolidate the discussion of Section 1 as follows:

1. Threat analysis conducted by the HC has determined the mission of MC and UC, specifying weapon systems and establishing the manning levels.

2. Staff analysts developing the OP.R. Index utilize the defined mission of MC (and UC) to initiate analysis of FACTORS, ELEMENTS, etc.

3. Analysis staff action identifies all necessary parameters of the Index from data collected on MC and UC.

4. The OP.R. Index orients operational performance to achieve desired MC mission and objectives.

5. Resulting unit performance (POSTURE) is compared with desired (optimal) results for:

a. Organization correction of discrepancies.

b. Further threat analysis (case where existing system is not capable of meeting defined threat).

FIGURE 3.4 shows in block diagram form the interactions of an Index analysis.

FIGURE 3.5 shows the OP.R. Index in a functioning state.

SECTION 2

2.1 READINESS MEASUREMENT

We have outlined "what" we are attempting to measure. The desired result is a compact quantification of readiness POSTURE that contains maximum information. As the staff analysis proceeds and ELEMENTS are defined for UC they will be, in the general case, incommensurable quantities. There is no known ratio scale that will permit direct comparisons of the incommensurables. This problem is circumvented by the use of VALUES (v_j). We associate with each e_{ij} a corresponding weight or VALUE, e.g., it is worth VALUE (v_j) toward operational readiness for completely satisfying e_{ij}.

2.2 OBTAINING FACTORS

The previous illustration of the ASW squadron (supra, Section 1.4.D) along with the definition of a FACTOR describe a "functional quality" of the Unit Command ($UC_K^{(ASW)}$) that the analyst seeks to discover.

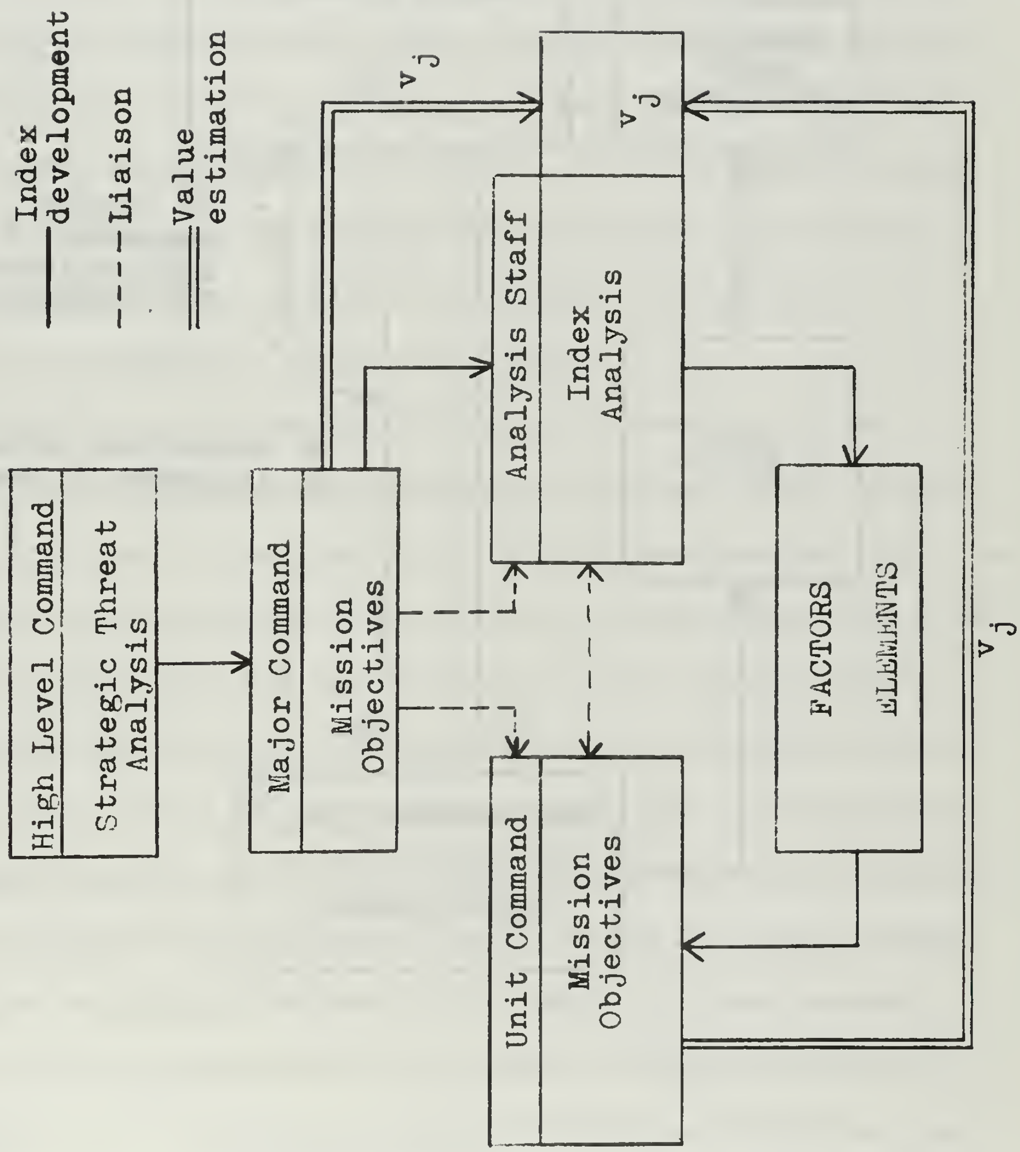


FIGURE 3.4

INDEX ANALYSIS

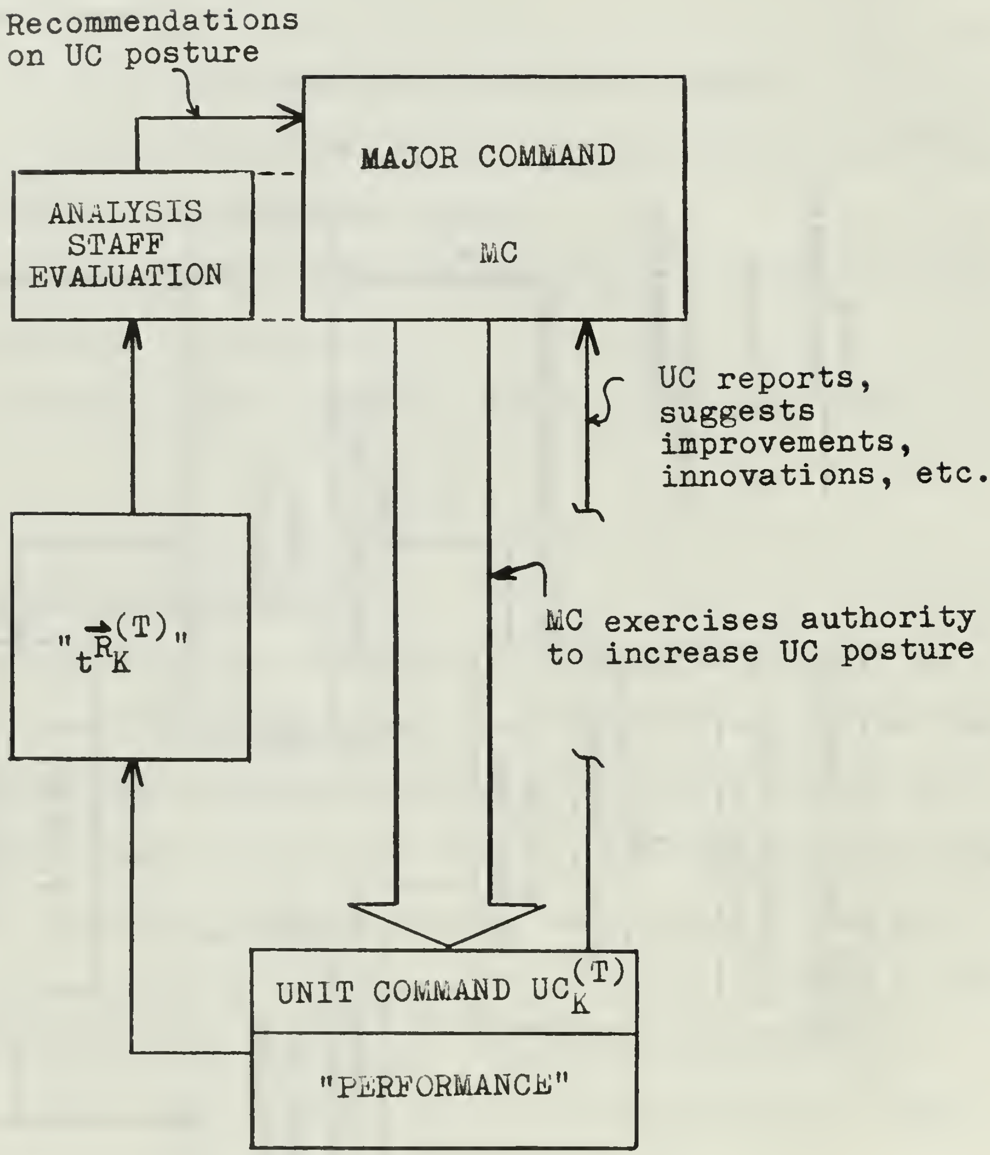


FIGURE 3.5

FUNCTIONING INDEX

In the theory of this Index model an appeal will be made (at a later stage in Section 2.5) to the scientific methods of FACTOR ANALYSIS. The appeal is derived from the need to distribute the VALUE v_j of an ELEMENT e_{ij} among the FACTORS (F_i), since we have seen that a particular ELEMENT may describe the capability of the $UC_K^{(T)}$ in one or more FACTORS. As has been stated in the opening discussion of Section 1.3, we desire to arrive at a number or set of numbers that contain a great amount of information, i.e., for any one number or "small" set of numbers that satisfy predetermined conditions, we (e.g., the Major Command) may be reasonably assured that the desired level of operational readiness is being maintained. The objective is to display as compactly as is reasonable the POSTURE of all military units.

In defining (designating) FACTORS (F_i) by means of factor analysis, we must assume that ELEMENTS can be defined by the analysts and that batteries of investigations, surveys, questionnaires, etc., (as appropriate) can be designed to obtain the v_j in such a manner that the results are consistent with the compilation of data (called "test scores" in the literature) as in factor analysis. The FACTORS (F_i) as defined for this model will in general be considered as being strictly those broad functions of the Unit Command which most directly influence readiness capabilities. Depending upon the method of factor analysis used in the case being considered (since there are several methods fitting various circumstances), the statement is made that FACTORS (F_i), in general, would be completely defined (or designated) after a final analysis of ELEMENTS and VALUES v_j.

Having made this broad statement concerning factor analysis, we note that conversely one may establish a hypothesis that certain FACTORS exist and then establish the correctness of the hypothesis under empirical data. It is in this sense that the use of factor analysis is proposed in this model. One (of several) means of doing this is called MULTIPLE GROUP FACTOR ANALYSIS, which will be discussed in Section 2.5. We would desire to confirm the assumptions that our "hypothetical" FACTORS (F_i) exist and additionally to estimate (or at least find a reasonable approximation) from our data how ELEMENTS affect FACTORS. In the first instance, if this does not turn out to be the case, it may not be of major consequence as a re-definition of FACTORS should be possible. As regards the division of VALUES (v_j) for the ELEMENTS, if for any reason the results obtained are incompatible (in some sense) or are obviously not usable, more serious difficulties are probably involved. These could conceivably range anywhere from biased methods of estimating v_j to totally inappropriate definitions of ELEMENTS. (It is to be noted that this use of factor analysis, as proposed, appears in harmony with the uses described in the literature. The technique was originally designed to measure (describe) psychological variables; the use here in the measurement of subjective (psychological) values is analogous.)

Analysis conducted on the Unit Command's mission and operational characteristics is suggested as normally leading to definition of FACTORS as was implied by the ASW illustration where the three FACTORS, (F_1, F_2, F_3), were given.

2.3 OBTAINING ELEMENTS

One primary input is necessary for determining the ELEMENTS. This input is the result of the military system analysis. (As this model has proposed establishing the FACTORS (F_i) in advance, the use of the "i" and "j" notation is consistent.) The analyst ultimately obtains

e_{ij} (goals, requirements, etc., <u>supra</u>, Section 1.4.B) from operations analysis in light of the UC mission; from already existing requirements established by MC or HC; from mathematical analysis; or by subjective methods. The e_{ij} are the ELEMENTS of F_i which exhibit the UC's operational readiness in the F_i dimension. Once the e_{ij} are defined, attention can be directed to the VALUES v_j corresponding to each e_{ij}. Emphasis must be placed on identifying the "set of e_{ij} that are essential"; temptations to define "too many" e_{ij} should be avoided. It may be that the particular military system under study has previously established a variety of requirements by the direction or instruction of higher authority (or by self-initiation).† This data will provide a wide base to commence the search for the significant e_{ij}. In general, defining (establishing) ELEMENTS in quantified terms will be desirable if possible, avoiding qualitative description so as to facilitate the procurement of the VALUES. The obtaining of ELEMENTS in the manner proposed is consistent with the planning involved in seeking any objective in any field (e.g., in the business world, management seeks to plan their operations, training, production, etc., in light of making profit). Essentially, it involves (systematically) establishing all of the intermediate goals, requirements, qualifications, etc., subject to certain constraints, that <u>must</u> be achieved at <u>specified</u> levels before any hope of attaining the end result (capability to do the mission) may be realized. Specifically, one approaches any task by first defining what that task must be <u>comprised of</u> in its most elementary (fundamental) aspects.

†It is likely that both cases cited will exist.

2.3.A. MINIMUMS ON ELEMENTS (m_j). For any time period "Δt" that the Index scheme prescribes as a "Performance Evaluation Interval," a given Unit ($UC_K^{(ASW)}$) will accomplish each e_{ij} to a measurable extent, i.e., $UC_K^{(ASW)}$ will have "some" degree of success in attaining each goal, e_{ij}. $UC_K^{(ASW)}$ will do so either in full, partially or not at all. This is the general case, and the degree to which the Unit attains each e_{ij} is a "performance level" which is a percentage denoted $b_j:(0 \leq b_j \leq 1)$. The "j" subscripts correspond. In certain circumstances, depending on the character of a particular ELEMENT, e_{ij}*, it may be necessary to establish minimum conditions such that if the minimum prescribed level of performance in e_{ij}* is not achieved during Δt, special notification, report, etc., to the Major Command is necessary. These minimums should be specified for each e_{ij}.

Define MINIMUM CONDITION:

$m_j \equiv$ The lowest acceptable performance level for $b_j (0 \leq m_j \leq 1)$. The subscripts correspond to ELEMENTS "j". The m_j set the lower bounds of the Unit Command performance level b_j (as above).

As an example of minimum performance levels and utilizing the previous illustration of the ASW squadron, consider the following: Let e_{23} = Average aircraft availability for the reporting period: 80%. Additionally, specify 60% as a "minimum condition" on the performance level. In this example, total accomplishment of e_{23} means the squadron's aircraft availability remains 80% or more. And the minimum condition m_3 equals 60%. Therefore the "performance level" b_3 is bounded on the interval $(.6 \leq b_3 \leq 1.0)$. For performance level $(0 \leq b_3 < .6)$ the squadron will have to report the circumstances to the Major Command giving all the details of why they cannot keep their planes in a satisfactory operating condition.

2.3.B. PRIORITIES LIST. To facilitate the defining and VALUE estimation process of e_{ij}, a "Priorities List" may prove useful. It may be established by sorting the e_{ij} as follows:

1. Items e_{ij} of F_i which are mandatory for OP.R.; b_j has positive lower bound m_j.

2. Items e_{ij} of F_i which significantly enhance OP.R.; b_j has non-negative lower bound m_j.

3. Lesser items e_{ij} of F_i which reflect OP.R. but for which the lower bound m_j on b_j is zero.

The list of a Priorities List will, in general, depend upon the complexity of the system.

2.4. VALUATION (v_j) OF ELEMENTS (e_{ij})

The definition and purpose of assigning VALUES v_j were given in Section 1.4.C. Further mention of the purpose of assigning value to ELEMENTS was made in Section 2.1.

The v_j will constitute the most intricate part of Index analysis. It will not be straightforward in most cases. There is a body of literature devoted to the measurement of relative values. The content will not be reproduced here; however, several suggested means of approaching the value problem will be given. The following methods of attack are offered which may (or may not) be appropriate in given circumstances.

The methods are

1. Analysis staff estimation of v_j (by the analysis personnel).

2. Unit Command estimate of v_j (participation by selected individuals, groups or the entire Unit).

3. Expert estimates of v_j (selected personnel of known reputation in the TYPE Unit being Indexed, e.g., TYPE ASW).

4. Combined estimates of v_j (from 1, 2, or 3).

Depending upon the method of inquiry, the VALUES that result may possibly serve to substantiate or to reject the choice of a particular ELEMENT $e_{ij}*$, e.g., if the VALUE estimation process turns out to have assigned uniformly negligible VALUES (weights) to some $e_{ij}*$, then it may be that $e_{ij}*$ does not "significantly reflect" readiness capability in the Unit at all. Analysts may note either substantiation of $e_{ij}*$ in some sense or rejection of $e_{ij}*$ in some sense during the VALUE estimating process. Again depending upon the inquiry methods, new ELEMENTS may be discovered that were not previously considered, e.g., if the inquiry is conducted throughout "many" Units, leading questions may be asked which seek participant responses concerning ELEMENTS.

VALUE estimation process is the term used here to label blanketly the procedure that confronts all cognizant members of the MC-UC relationship with the task of <u>actually</u> specifying what is important in terms of defined missions. It is a process that requires participants to establish which particular requirements, goals, etc., <u>must</u> be achieved to satisfy the dictates of the mission. It is only logical to assume that certain requirements (ELEMENTS) are more important than others. However, if it turns out that they are not, so be it; the objective has been to <u>demand</u> that individuals within the military system concerned (those most closely associated with the requirements and problems involved) provide their subjective determinations of which requirements are important and in what relationship. (Note that side benefits may be derived from such a process in that once certain requirements, goals, etc., have been specified as vital, any externally imposed circumstances preventing the Unit Commands from pursuing these requirements are justification for close scrutiny and investigation by the MC and/or HC as to why such circumstances were imposed, if the reasons are not self-evident.)

VALUE estimation in the Index scheme should be a dynamic process. The need exists for periodic updating of an Index just as it does for any other aspect of modern military operations. Updating of the entire scheme would also be required after major changes in equipment, redesignation of missions and objectives, or any time the Unit Command's military orientation shifts.

Appendix I discusses some of the concepts involved with the VALUE estimation process entailed in Index scheme development.

2.5. FACTOR ANALYSIS

In Section 1.4.D., a brief illustration of the Operational Readiness Index for an ASW squadron was given. The relationship between FACTORS and ELEMENTS was defined in Section 1.4.B. In Section 2.2 mention was made of the fact that we desire to establish the "effect" of e_{ij} upon F_i. It is clear that ELEMENTS may affect (belong to) more than one FACTOR. A procedure that suggests itself as a possible (partial) resolution of this difficulty is the technique FACTOR ANALYSIS.

Within the theory of factor analysis there exists a variety of specific techniques or methods for determining descriptive FACTORS (characteristics) from a set of data. Such techniques include Principal Component Analysis, Bi-Factor Analysis, the Centroid Method, etc. As this paper is a basic study of operational readiness for military force posture and not a survey of the techniques of scientific factor analysis, only one method has been chosen for illustration. That method is called

MULTIPLE GROUP FACTOR ANALYSIS. It has been chosen solely on intuitive grounds as it appears to provide a reasonable approach to the task of estimating ELEMENT influence upon the FACTORS F_i. This is not to say that in fact some other method (as above) may be more appropriate in a given set of conditions. Additionally, none of these techniques has been tested empirically by this author.

The following discussion concerns the assumptions behind Multiple Group Factor Analysis when applied to the readiness problem.

At this point a distinct departure from the notation of ELEMENTS will be made. The subscript "i" will be dropped from the e_{ij} (becoming e_j) for reasons that should shortly become clear as the "group" concept of Multiple Group Factor Analysis is illustrated. (For other factor analysis methods it may be useful to retain the double subscripts on the ELEMENTS; for the multiple group solution this is unnecessary.)

Assume that staff analysts specify $(F_1, F_2, \ldots, F_r)$ as FACTORS for the Unit Command being Indexed. They have defined "L" requirements (ELEMENTS) to exist, viz., $(e_1, e_2, \ldots, e_L)$. Furthermore, from surveys similar (in nature) to that depicted in FIGURE 3.6, assume that they have been able to "group" ELEMENTS belonging to FACTORS. Assume that the results of the survey have revealed some overlapping of the groups of e_j but, for the purpose of this illustration, a "clear enough" distinction exists among the groups of e_j that the analysts are justified in arranging the sets in a non-overlapping manner. Furthermore, they have specified "r" groups of e_j's, i.e., they have partitioned the set of e_j's into "r" uniquely distinct groups. (Note that although a "clear enough" distinction among the ELEMENTS exists so that unique grouping is possible, this does not necessarily imply that a particular ELEMENT will affect only the FACTOR that it is grouped with.)

e_1: Requirement for 75% of Pilots to be Qualified in ASW Tactics		For Research Personnel Only
Check the appropriate box that best describes your estimation of the importance of e_1 (above) with respect to the mission of your squadron.		
"I consider e_1 (above) ..."	Check One	v_1 assigned to e_1
1. Mandatory for Ops Readiness	[ ]	100
2. Essential for Ops Readiness	[ ]	80
3. Important for Ops Readiness	[ ]	60
4. Fairly Important for Ops Readiness	[ ]	40
5. Concerns Ops Readiness Somehow	[ ]	20
6. Does not concern Ops Readiness at all	[ ]	0
"With respect to Operational Readiness, e_1 (above) primarily affects which of the following:"		r=3
1. Squadron Operations	[ ]	F_1
2. Squadron Maintenance	[ ]	F_2
3. Squadron Personnel Capabilities	[ ]	F_3
4. Other (write in) ________________	[ ]	

FIGURE 3.6

HYPOTHETICAL SURVEY SHEET

The diagram depicts the notions involved in a VALUE estimation process (not necessarily indicating a preferable survey technique).

Multiple Group Factor Analysis begins from the assumptions given in the preceding paragraph.

During the VALUE estimation process each of the "n" Unit Commands (for example, the various ASW squadrons) has furnished its estimate of v_j for all j. Denote these "estimates" as $\overline{v}_{jK}$. These are "observed" estimates for the "n" Unit Commands, $UC_K^{(ASW)}$, (K=1,...,n). Estimates are required from each command in order to use factor analysis techniques (of any variety) since they depend upon statistical methods. (In the literature of factor analysis, these estimates are considered "test scores.") As each Unit Command has provided estimates $\overline{v}_{jK}$, form the average of these quantities as

$$\hat{\overline{v}}_j = \frac{1}{n} \sum_{K=1}^{n} \overline{v}_{jK}, \quad j=1,\ldots,L$$

(The circumflex denotes an average value of $\overline{v}_{jK}$.)

As previously defined, v_j is the VALUE (weight) awarded to the Unit Commands for totally accomplishing ELEMENT e_j. After the VALUE estimation process this VALUE (v_j) is given numerically by $\hat{\overline{v}}_j$ (as above).

The utility of applying factor analysis is that from information contained in the "set of estimates" ($\overline{v}_{jK}$'s) we desire to estimate (approximate) how the quantity $\hat{\overline{v}}_j$ is to be distributed among the FACTORS (F_i) according to the influence that e_j has upon F_i. $\hat{\overline{v}}_j$ will be divided into "r" parts, i.e., some percent (denoted: $p_{ji} \geq 0$) of $\hat{\overline{v}}_j$ will be assigned to each F_i though that percent may be zero for one or more F_i. Referring to the ASW squadron, where r=3, and F_1, F_2 and F_3 were defined along with e_1, let v_1=10 and p_{11}=25%, p_{12}=75% and p_{13}=0%. Then if goal e_1 (using the notation of this section where the "i" was omitted) was satisfied completely according to its definition, the ASW squadron would receive weight 2.5 for F_1, 7.5 for F_2, and 0 for F_3.

The purpose of all this is to take the ELEMENTS e_j, establish their VALUE (quantified as $\hat{\bar{v}}_j$), which permits comparison, and group them into "r" groups; and hence by Multiple Group Factor Analysis approximate the division of each v_j among the FACTORS F_i.

The Unit Command estimates $(\bar{v}_{jK})$ form a Lxn matrix denoted by V. (See FIGURE AI-2 of Appendix I.) This is the raw data for L statistical variables (the v_j) for the n Unit Commands. The row-wise ELEMENTS of the V matrix may be considered the coordinates of L <u>points</u> v_j (j=1,...,L) in an n-space. Alternatively, these L points may be called "vectors." Then the L variables have a vector representation given by

$$2.5.(1) \qquad \vec{v}_j = (\bar{v}_{j1}, \bar{v}_{j2}, \ldots, \bar{v}_{jn}) \qquad j=1,\ldots,L$$

The data from matrix V can be reduced to standard form and correlation coefficients computed among the variables.† This is normally done before a factor analysis computation.

Denote the standardized variables of V as a matrix Z.

$$Z = (z_{jK}) \quad \text{where,} \quad z_{jK} = \frac{\bar{v}_j - \hat{\bar{v}}_j}{\sqrt{\dfrac{\sum_{K=1}^{n} (\bar{v}_{jK} - \hat{\bar{v}}_j)^2}{n}}}$$

The product of Z by its transpose Z^T is equal to the correlation matrix multiplied by the scalar n (for the "n" Unit Commands).

$$ZZ^T = nR \qquad \text{or,} \qquad R = \frac{1}{n} ZZ^T$$

†The discussion of factor analysis presented here is drawn directly from Chapters 2, 3, and 4 of Modern Factor Analysis (see Bibliography).

Factor analysis is concerned with suitably choosing appropriate main diagonal ELEMENTS (replacing the usual "ones") such that a matrix R_D is obtained.†

Factor analysis computations then obtain the matrix A such that

$$R_M = AA^T \quad , \quad R_M \doteq R_D$$

where $A=(a_{ji})$ is an (Lxr) matrix called a factor pattern and R_M is a reproduced correlation matrix with element by element approximations for R_D. The symbol ($\doteq$) denotes an "approximation" of equality. Thence,

$$AA^T \doteq \frac{1}{n} ZZ^T$$

The approximation is determined to be "suitable" where a residual correlation matrix R_S,

$$R_S = R_M - R_D \ ,$$

"satisfies" the analyst. The factor pattern $A=(a_{ji})$, (Lxr), is the matrix of coordinates for the variables v_j within the FACTOR space $F_1,\ldots,F_r$. Therefore, equation 2.5.(1) has a vector representation in the r-space given by

2.5.(2) $\quad \vec{v}_j{}^* = (a_{j1}, a_{j2}, \ldots, a_{jr}),$

or $\quad \vec{v}_j{}^* \dashv a_{j1}\hat{f}_1 + a_{j2}\hat{f}_2 + \ldots + a_{jr}\hat{f}_r \qquad j=1,\ldots,L,$

†These values are called "communalities" in the factor analysis literature.

where: 1) the $\hat{f}_i$ are the same unit dimension vectors given in Section 1.4.D, and 2) the a_{ji} are the scalar elements of a matrix A (Lxr) discussed above.†

It is acknowledged that this discussion of the theory of factor analysis has been far from rigorous or complete; in fact, much has been omitted for the sake of brevity. The purpose has been to give the reader a brief notion of the concepts involved, not to offer a precise formulation for computing the A matrix. For a complete, detailed and rigorous presentation of the entire theory and computational methods the reader is referred to Modern Factor Analysis (see Bibliography) from which this discussion was drawn.

Recall we desire to divide $\hat{\bar{v}}_j$ into "r" parts according to e_j's "effect" upon F_i. Now it may be observed that there exists a correspondence between the vector $\vec{v}_j$ (equation 2.5.(1)) and the scalar average estimate $\hat{\bar{v}}_j$. If we assume that there exists an approximate one to one correspondence between the factor coefficients (the a_{ji} of equation 2.5.(2)) and the manner in which $\hat{\bar{v}}_j$ should be distributed (divided) into the "r" percentages ($p_{ji} \geq 0$) then the a_{ji} will indicate how this distribution (division) might be carried out.

Before leaving this discussion of factor analysis two points (concerning the subject) bear mentioning. These points relate to the (at present) most subjective aspects of factor analysis.

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†The coefficients a_{ji} in equation 2.5.(2) are implied to be orthogonal coefficients of the $\hat{f}_i$. In a factor analysis computation this may consist of a transformation from an initial "oblique solution" to an orthogonal system.

1. First, the attempt made in this paper has been to derive information about the "underlying constructs" which have been defined here as FACTORS F_i, but it must be emphasized that

> There is no search for timeless, spaceless, populationless truth in Factor Analysis; rather, it represents a simple straightforward problem of description in several dimensions of a definite group functioning in definite manners, and he who assumes to read more remote verities into the factorial outcome is certainly doomed to disappointment.[2]

In other words, the general approach in this paper has been establishing, a priori, the FACTOR space--that this should be the case seems intuitively appealing; however, the results of surveys (VALUE estimation processes) as sketched in this paper may reveal that ELEMENTS are providing information concerning more than (or less than) the original hypothesized FACTORS (F_i). Only data from specific surveys can answer a given hypothesis. (It is stated once again that no empirical analysis has been conducted by this author to in fact conclude that VALUE estimation and factor analysis can be linked together in the general form proposed in this paper, although every indication (by analogy) in the literature seems to reveal promise.)

2. The second point to mention concerns possible additional orthogonal rotations of the A matrix. Often, an initial factor solution provides only a stepping stone to "more desirable" multiple factor solutions. (This is, in general, an accepted concept discussed in factor analysis literature.) As there is latitude for subjective determination of what constitutes a "more desirable" solution, a method has been proposed by the scientific community professionally engaged with factor analysis to definitize mathematically "more desirable" solutions. This method is the <u>varimax solution</u> (varimax criterion).[3] It has been developed by Kaiser and is presently available for use on high speed digital computers.

2.6. OPERATIONAL READINESS INDEX

2.6.A. OPTIMAL INDEX. We assume that factor analysis has provided a set of coefficients a_{ji} $(0 \leq a_{ji} \leq 1)$ that indicate how the partitioning of v_j into percentages is carried out. As we are assuming an "r" space with mutual orthogonality existing for the FACTOR axes $(F_1, F_2, \ldots, F_r)$ defined in Section 1.4.D, the percentages p_{ji} (supra, Section 2.5) are computed from the a_{ji} as

$$p_{ji} = \frac{a_{ji}\cos(\alpha_{ji})}{\left(\sum_{i=1}^{r} a_{ji}^2\right)^{1/2}} \geq 0, \quad \sum_{i=1}^{r} p_{ji} = 1, \quad j=1,\ldots,L$$

where $\cos(\alpha_{ji})$ are the direction cosines of $\vec{v}_j^*$, when considered as a vector in "r" space as in equation 2.5.(2). (See FIGURE 3.7.) Hence, each estimate $\hat{\bar{v}}_j$ is divided into "r" parts, each of the form $\{p_{ji}(\hat{\bar{v}}_j)\}$ assigned to the corresponding FACTOR "i".

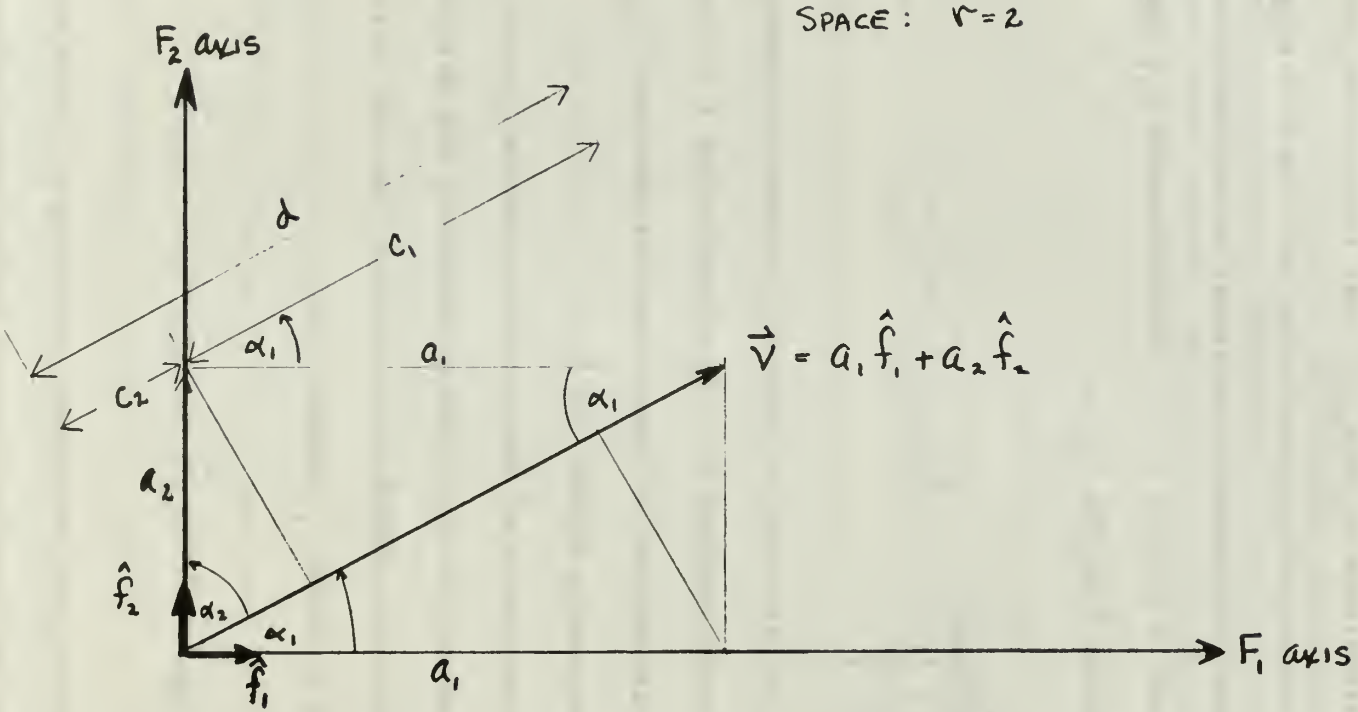
Recalling the discussion of Section 1.4.D, (where F_i^* and F_i' were introduced as scalars for the "optimum condition" and Unit Command "posture," respectively, for FACTOR i), we may now form the scalar sum for each, constructed from the $\hat{\bar{v}}_j$ scalars. Let

$$\text{2.6.A.(1)} \quad F_i^* = \sum_{j=1}^{L} (p_{ji})(\hat{\bar{v}}_j) = p_{1i}\hat{\bar{v}}_1 + p_{2i}\hat{\bar{v}}_2 + \ldots + p_{Li}\hat{\bar{v}}_L.$$

"j" indexes the weights v_j for completely satisfying e_j. Each ELEMENT "j" gives some percent of its weight to each FACTOR where that percent may range from 0% to 100%.

Equation 2.6.A.(1) defines the maximum VALUE that a Unit Command may obtain in FACTOR "i". Hence the OPERATIONAL READINESS INDEX for

SPACE: $r = 2$



$c_1 = a_1 \cos\alpha_1$

$c_2 = a_2 \cos\alpha_2$

$d = c_1 + c_2 = \sum_{i=1}^{2} c_i = \sum_{i=1}^{2} a_i \cos\alpha_i$

$d = \left(\sum_{i=1}^{2} a_i^2\right)^{\frac{1}{2}}$

<u>denote</u>: P_i as the percent of d that c_i contributes.

$$P_i = \frac{c_i}{d} = \frac{a_i \cos\alpha_i}{d} = \frac{a_i \cos\alpha_i}{\left(\sum_{i=1}^{2} a_i^2\right)^{\frac{1}{2}}}$$

FIGURE 3.7

ASW (r=3) (defined in Section 1.4.D) is given by

$$\vec{R}^{(ASW)}_{opt} = \sum_{i=1}^{3} F_i{*}\hat{f}_i$$

$$= \sum_{i=1}^{3} \left[\sum_{j=1}^{L} (p_{ji})(\hat{\bar{v}}_j) \right] \hat{f}_i$$

by using 2.6.A.(1) where the ASW squadron was assumed to have r=3 FACTORS.

2.6.B. UNIT POSTURE. During the time interval over which unit performance is measured, the ASW squadron will achieve a set of performance levels (numbers) "b_j" ($0 \leq b_j \leq 1$) of Section 2.3.B. Then the scalar sum for the Unit Command POSTURE in FACTOR "i" (viz., F_i' of Section 1.4.D) may be formed as

2.6.B.(1) $$F_i' = \sum_{j=1}^{L} (b_j)(p_{ji})(\hat{\bar{v}}_j) \qquad i=1,\ldots,r$$

Therefore, the Unit Command POSTURE evaluated at "t" (${}_t\vec{R}^{(ASW)}_K$) will be the "particular" set (primes) of performance levels (b_j') for that period introduced into 2.6.B.(1).

$${}_t\vec{R}^{(ASW)}_K = \sum_{i=1}^{3} F_i'\hat{f}_i$$

$$= \sum_{i=1}^{3} \left[\sum_{j=1}^{L} (b_j')(p_{ji})(\hat{\bar{v}}_j) \right] \hat{f}_i$$

If minimum conditions "m_j" (lower bounds ($0 \leq m_j \leq b_j \leq 1$)) were assigned to each ELEMENT, then for any $b_j' < m_j$, reports must be forwarded to the Major Command giving details of the unsatisfactory performance.

2.6.C. CRITERION. The criterion for specifying the minimum readiness posture $R_{min}^{(ASW)}$ (*supra*, Section 1.4.D) will necessarily be determined from the circumstances peculiar to the given situation, just as minimum conditions "m_j" (*supra*, Section 2.3.B) are peculiar to the given situation. Three types of criterion are readily available (whether they are applicable to a specific case is another question).

1. Magnitude and Direction Criterion
2. Magnitude (only) Criterion
3. FACTOR Criterion (and extension)

The first criterion states that $R_{min}^{(ASW)} = h(\vec{R}_{opt}^{(ASW)})$ is defined (μ and β are given) by:

2.6.C.(1)
$$h(\vec{R}_{opt}^{(ASW)}) \equiv \begin{cases} h_1(\vec{R}_{opt}^{(ASW)}) = \mu|\vec{R}_{opt}^{(ASW)}|, & 0<\mu\leq 1 \\ h_2(\vec{R}_{opt}^{(ASW)}) = \cos(\beta), & 0°\leq\beta<90° \end{cases}$$

The vector comparison function "g" is defined by:

2.6.C.(1a)
$$g({}_t\vec{R}_K^{(ASW)}) \equiv \begin{cases} g_1({}_t\vec{R}_K^{(ASW)}) = |{}_t\vec{R}_K^{(ASW)}| \\ g_2({}_t\vec{R}_K^{(ASW)}) = \dfrac{\vec{R}_{opt}^{(ASW)}\,[\text{dot}]\,{}_t\vec{R}_K^{(ASW)}}{|\vec{R}_{opt}^{(ASW)}|\,|{}_t\vec{R}_K^{(ASW)}|} \end{cases}$$

Then if,

$$g_1 \geq h_1 \quad \text{and} \quad g_2 \geq h_2 ,$$

$UC_K^{(ASW)}$ is <u>OPERATIONALLY</u> <u>READY</u>,

and if

$$g_1 < h_1 \quad \text{or} \quad g_2 < h_2 \quad \text{(or both)},$$

$UC_K^{(ASW)}$ is <u>NOT</u> <u>READY</u>.

μ and β are criterion parameters that must be established by the analysis staff. The parameters determine the degree of latitude that the Index permits for acceptable Unit performance. In essence, the relations 2.6.C.(1) and (1a) define parameterized measures of effectiveness since we are measuring a POSTURE versus an optimally effective state ($\vec{R}_{opt}^{(ASW)}$).

Hence, $R_{min}^{(ASW)}$ defines two conditions (h_1 and h_2) that the Unit Commands must satisfy to be classified READY and "g" defines the appropriate manner (g_1 and g_2) for making the comparisons.

The first criterion establishes the requirement for a $UC_K^{(ASW)}$ to perform at a certain level and additionally to balance its military operations among the FACTORS.

The second criterion is equation 2.6.C.(1) for "h_1" only and again the relations $g_1 \geq h_1$ and $g_1 < h_1$ determine READINESS ratings. The second criterion specifies that a certain "level" of operation is necessary to maintain (at least) a desired OPERATIONAL READINESS minimum.

The FACTOR criterion restricts the performance of each $UC_K^{(ASW)}$ to at least a certain minimum level in <u>each</u> F_i. The restriction is given by $F_i' \geq c_i F_i^*$ for all "i", where F_i^* is the "optimum of FACTOR i," $0 \leq c_i \leq 1$, and F_i' is the Unit's "POSTURE" in FACTOR i at reporting period "t". An extension of this criterion can be established in conjunction with the minimum conditions for ELEMENTS$(0 \leq m_j \leq 1)$ defined in Section 2.3.A. This would imply that Units must not only satisfy criterion (3) to be operationally ready but must also comply with all of the lower bounded conditions imposed by all defined m_j. This is a more stringent criterion and requires that each $UC_K^{(ASW)}$ must satisfy to a specific degree the requirement of each e_j^* that has a defined m_j^* which is greater than zero.

2.7. PLANNING

The discussion of this chapter thus far has closely followed the philosophy developed in the previous two chapters regarding operational readiness and its measurement. The Index model as designed provides a basis for determining POSTURE by comparison of performance levels with clearly defined goals. Several criteria have been offered to permit comparison as dictated by the specific circumstances of a given case. It remains to be established how the Index can provide information to the Major Command concerning POSTURE and deficiencies that may exist.

First, POSTURE information to the MC is directly available from the Index. If the Index minimum conditions $R_{min}^{(T)}$ are satisfied, Units are "ready" within the context of defined goals. By definition any performance levels (b_j) which have <u>not</u> satisfied the minimum conditions (m_j) must be reported through the proper channels to the proper authority. Secondly, if the Index is satisfied, staff readiness analysts may tell from the Index not only that the Units are ready, but just as importantly, that all defined ELEMENTS are being satisfied. We have a compact set of numbers that reveal the degree of readiness POSTURE and additionally indicate that all specified readiness indicators (the ELEMENTS) are being met. The value of such information is obvious. Thirdly, by charting readiness Index POSTURES over time a clear picture of the readiness domain is available. For a given Unit type that has widespread (among most or many of the TYPE T Units) and common problem areas, one will observe consistently low F_i' values. For $F_3 \equiv$ ASW Squadron Personnel, if F_3' is consistently low for all (or many) of the $UC_K^{(ASW)}$, this will indicate immediately that a problem area exists and what that area consists of. It is assumed that by further investigation into the performance levels (b_j) affecting F_3, the trouble may be further isolated. Thus, <u>plans</u>, <u>programs</u>, etc., for correction may be initiated. We find, then, that the Index (as developed) has within its framework a definite means for measurement and the subsequent determination of correction when needed.

In regard to planning for operations, supply and logistics needs, etc., the Index provides a systematic method of approach. We have assumed that it was possible to specify (by means of the VALUE estimation process) which ELEMENTS demanded the most attention with respect to readiness posture. Having established the importance of an ELEMENT it is possible to utilize these VALUES (V_j) to plan what resources are needed for Unit operations in general or to plan how they may be used if given. These conditions (established by the model) lend themselves quite easily to a programming scheme.

Let x_j be the level of performance <u>to be determined</u> for each ELEMENT $e_j (j=1,\ldots,L)$. (For programming, the subscript "i" is not required on ELEMENTS.) Let v_j be the VALUE of e_j as before. <u>Assume</u> that resources of a specified type (kind) are allocated at a level B_k

$(k=1,\ldots,s)$. There are "s" ($s \leq L$) commensurable types of resources. These could be dollars, flight hours, weapons, man-hours available, training-hours available, etc. Further, define c_{kj} as a "unit cost" (in the programming sense) incurred for obtaining the requirements, goals, etc., defined for e_j. The subscript k corresponds to subscripts of B_k. These "unit costs" could be in terms of flight hours per pilot (or crew) to maintain a qualification, dollars per weapon, dollars per aircraft flight hour, hours of training required for a qualification, or man-hours for maintenance, etc. The objective, as before, is to maximize readiness posture. This can be done by maximizing performance levels (b_j) (supra, equation 2.6.B.(1)). Hence, maximize the sum of $\hat{\bar{v}}_j x_j$. The program is formulated (in principle) as:

$$\max_{x_j} \left\{ \sum_{j=1}^{L} \hat{\bar{v}}_j x_j \right\}$$

$$\text{s.t.} \quad C\vec{x} \leq \vec{B}$$

$$\vec{x} \geq \vec{m} \geq \vec{0} \;,$$

where: $C \equiv$ matrix of "unit costs"; $C=(c_{kj})(sxL)$

$\vec{x} \equiv$ vector of levels to be determined (Lx1)

$\vec{B} \equiv$ vector of resources allocated (sx1)

$\vec{m} \equiv$ vector of minimum conditions (m_j) for performance levels (supra, Section 2.3.A)

$\vec{0} \equiv$ the null vector

It may be that certain elements of C will be zero where e_j* is not concerned with some particular resource (and therefore not concerned with that "unit cost"). Also, it may be the case that some e_j* are not defined in terms of resources; in such a case the dimensions of the program are accordingly reduced.

The solution yields a set of x_j that determine what performance levels are optimal for the given resource level $\vec{B}$. It may be that a given $\vec{B}$ will not be consistent for the $\vec{m}$ constraining $\vec{x}$; in this case, clearly, the resources have been allocated at a level insufficient to establish maximum readiness. In effect, this says that if there is no feasible solution for the program, the resource level $\vec{B}$ is not sufficient. Additionally, by allowing $\vec{B}$ to vary while holding C constant, one may determine what $\vec{B}$ is required to obtain the optimal F_i*, or simply, what $\vec{B}$* is required for $\sum_{j=1}^{L} v_j$, since $\vec{B}$* will determine x_j at 100% for all j. Of course, this is not to say that the Units will perform at a maximum capability; actual performances b_j are subject to all of the variability of military operations. In short, the x_j are performances that can be expected from the given resources available <u>if</u> all goes perfectly.

CHAPTER III FOOTNOTES

[1] Raimon W. Lehman and Raymond L. Wellde, "Evaluation of Unit Readiness: ARSTRIKE DIVISIONS" (Master's thesis, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, 1965), page 69, quoting the Honorable Eugene M. Zuckert, Secretary of the Air Force, An Address, Industrial College of the Armed Forces (Washington, D. C.: 1963-64), p. 4.

[2] Harry H. Harman, Modern Factor Analysis (Chicago: University of Chicago Press, 1960), p. 85.

[3] Henry F. Kaiser, "The Varimax Criterion for Analytic Rotation in Factor Analysis," Psychometrika, 23 (1958), pp. 187-200.

SUMMARY AND CONCLUSIONS

This paper is based upon the thesis that a continuing effort must be exerted to increase operational readiness evaluation methods so that correction of deficiencies (discrepancies) can be made as higher readiness levels are sought. The effort here has been to assist in pointing the way. The analysis has specifically endeavored to "search" behind military readiness in the effort to discover "why" and "what" we are attempting to measure. The reasons for this are obvious; before attempting measurement of any sort, knowledge concerning purpose most often leads to method. Additionally, an exploration to probe the readiness measurement frontier was conducted by searching for sophisticated techniques that attempt <u>direct</u> measurement of what the man in the field is capable of doing with his given weapon system.

READINESS MEASUREMENT

1. The two major roles played by the military forces, viz., deterrence and local (limited) war suppression, continue to demand readiness measurement schemes of the highest capacity due to the fact that military posture in these roles has a vital effect on:

    a. United States foreign policy

    b. The policy and objectives of foreign nations

    c. Subsequent strategic threat analysis conducted by military defense planners

    d. Military planning and operations

2. For readiness measurement schemes that attempt direct measurement of unit (force) capabilities to carry out the assigned (defined) missions, accurate threat analysis is vital. This leads to the obvious

conclusion that the preponderence of effort involved in defense planning must be done in the initial threat analysis phases. It is immeasurably more important to devote time, effort and money to threat analysis in order to determine proper forces (and levels) than to attempt detailed measurement of force capabilities where "threats" are inaccurately assessed. Ideally, thorough and complete threat analysis is followed by thorough and complete force capability measurement.

3. Operational readiness measurement schemes must attempt to measure

a. Capability to counter the threat (combat potential)

b. Expenditure of allocated resources (efficiencies)

c. Use of men and machines (system utilization and materiel condition)

It is concluded by this writer that the most efficient means of doing this is by comparing explicitly defined goals, requirements, objectives, etc., with observed postures so that corrections can be made when and where needed. (This is quite consistent with the planning of any major undertaking; one determines and satisfies the intermediate conditions required before broader objectives can be realized.)

4. Readiness measurement schemes must be dynamic in nature. They should be so developed that the system being measured for readiness is an integral part of a total system which continues to evaluate threat, define goals, innovate and systematically pursue increased capabilities.

OPERATIONAL READINESS INDEX MODEL

1. The OPERATIONAL READINESS INDEX model developed has in a general (but consistent) fashion incorporated the philosophy developed

in Chapters I and II (summarized in 1-4 above). Whether such an evaluation scheme would be applicable in the exact form given (to include value measurement and factor analysis) could be determined only from further study as no empirical data were obtainable for analysis (due to the nature of the proposed method). The scheme would be applicable in any case, only under the assumptions (underscored) in Chapter III. Experts in the fields of operations analysis, value measurement and factor analysis would be required. A computer facility is fundamental.

2. The model as developed provides a general theoretical and exploratory framework for prospective readiness measurement schemes. The broad concepts of readiness factors, readiness elements (indicators), values (effectiveness weights), performance minimums, performance levels, etc., are germane and clearly applicable in concept to any scheme purporting to measure directly readiness.

3. The model in concept is clearly usable (even by individual Unit Commands) whether value measurement or factor analysis is available or not. This is due to the fact that the model demands in a fundamental way that analysis be conducted concerning the tasks and requirements which are essential for mission success; that priorities be assigned; and the minimum acceptable levels (for a "READY" rating) be set. At the very least this entails a commanding officer in conjunction with staff officers 1) examining in detail all aspects of unit operations which directly affect readiness, and 2) systematically pursuing the resulting tasks to obtain the desired posture. The greater the input of effort and analysis the more nearly the Index model will be approached.

It is hoped that this paper has placed sufficient emphasis on the fact that readiness evaluation schemes should ideally compare performance with defined (optimal) standards so that POSTURES may be increased. It is contended that the most fundamental method of doing this is by measuring the current capabilities of men-within-systems, insofar as possible, so that measured deficiencies can be recognized and corrected as increasingly superior performances and higher readiness levels are sought.

APPENDIX I

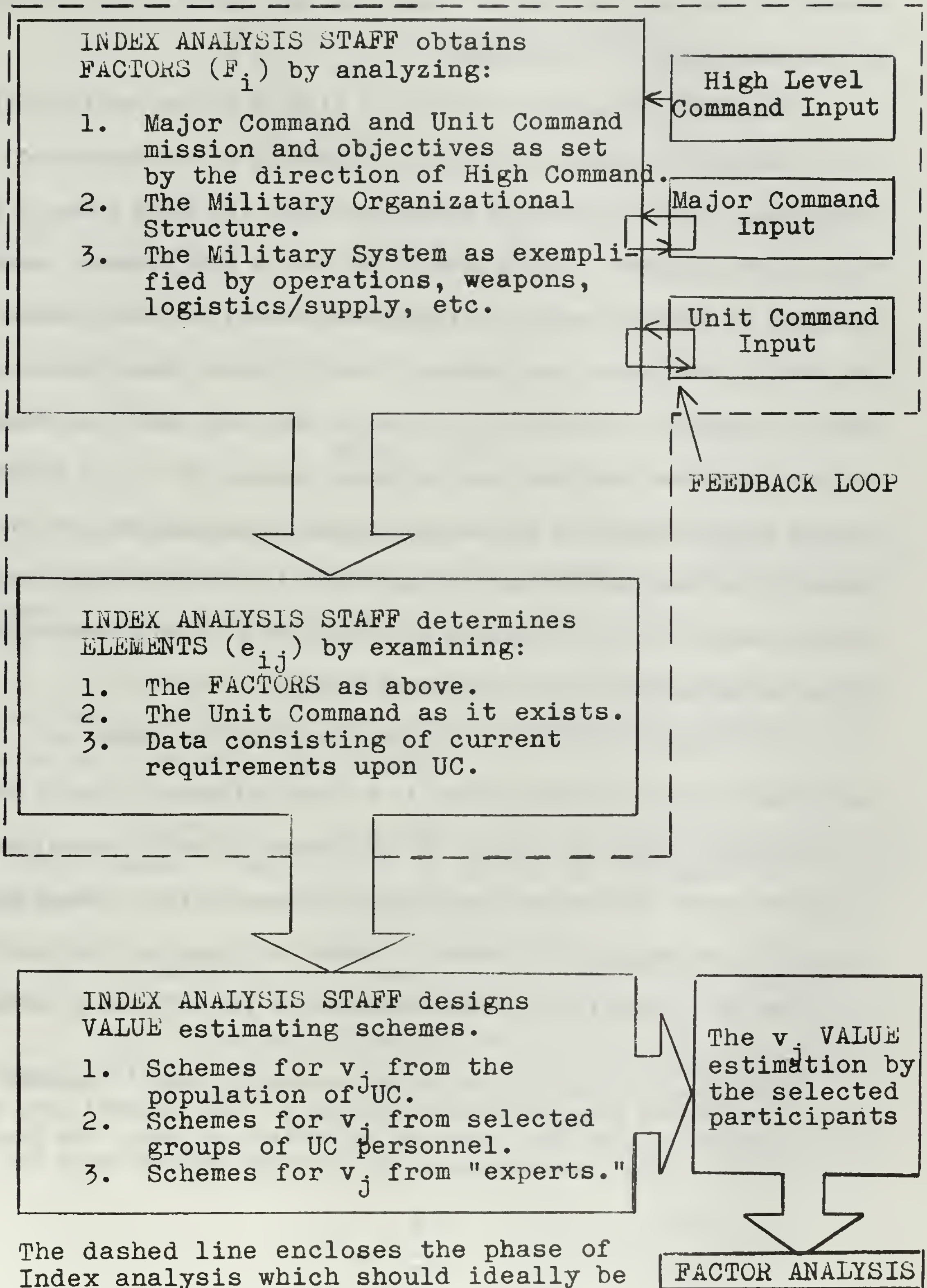
VALUATION OF ELEMENTS

The objective of this Appendix is to amplify the discussion of Section 2.4 of Chapter III. The VALUES necessary for the establishment of the Operational Readiness Index constitute a direct appeal to the theory of utility. At first this may seem to be a restriction that could cause a quantified Index scheme to be biased. May we first reply by stating that the entire process of readiness measurement is contingent in varying degrees upon the measurement of subjective values. The decisions rendered at even the highest levels concerning strategic threat analysis are to a substantial degree dependent upon subjectivity (concerning either data or decisions). There is simply no known way to avoid it. We state that until a superior method is developed, the techniques of utility theory, if not entirely satisfactory, nevertheless can be adequate and indeed quite useful.

The "VALUATION" process suggested for use in this model embraces an opinion expressed in the literature on value measurement which contends that in certain cases a better "feel" for relative value can be derived from group estimations.[1] Section 2.4, Chapter III, offered methods for obtaining the v_j. Essentially these methods implied that the search for the v_j be conducted from as large an input body as is considered reliable. The greater the number of estimates of the relative value (importance) of success in a given defined requirement or goal (e_{ij}), logically the greater will be the probability of accurately establishing the importance of each e_{ij}. It should be definitely established that the true "worth" (value) of accomplishing any defined goal is not obtainable. But this is not of direct concern; we may appreciate this fully by realizing that we are attempting to estimate the relative importance of conducting certain tasks, i.e., the tasks or requirements specified in definitive terms as being necessary for the particular military unit to attain a combat-ready posture.

At this point it should be made clear that the use of the techniques of factor analysis are specifically dependent upon statistical methods. For this reason the model, incorporating factor analysis as developed, is dependent on obtaining a broad base of estimates from the reliable sources at hand concerning the relative VALUES v_j. As the model is designed for the case where "numerous" units of the same TYPE are involved, this should present no major obstacle with respect to sources. (Supra, Chapter III, Section 1.2.)

We seek a set of numerical values that estimate the relative importance of the e_{ij}. FIGURE AI-1 is a Flow Diagram that depicts the procedural flow of events that lead to the "VALUATION" process. The dash-enclosed block at the top of the diagram represents the analysis phase in which the missions and objectives are analyzed. In this phase HC, MC, and UC make contributions to the analysis. Complete liaison between all parties is mandatory in order that all significant aspects of the mission are revealed. This is depicted by the feedback loops that appear. Three parallel processes are implied in the lower block. The first is an estimating process that renders equal importance to each input received. The other two are processes in which weights may (or may not) be attached to each input corresponding to the importance of that estimate as subjectively determined by the analysis staff



The dashed line encloses the phase of Index analysis which should ideally be characterized by a maximum of liaison among Commands and the analysis staff.

FIGURE AI-1

personnel.† The inputs to the factor analysis computations are the results of the VALUE estimation process and are symbolically depicted at the lower right of the diagram.

The VALUE estimation process will yield from the participants a set of numerical estimates for each v_j according to the individual participant. For illustration we may say there are three types of data that can be acquired: First, that of the entire Unit Command; second, the input of selected groups of individuals within the Unit Command; and lastly, the inputs from experts. We will expand these notions somewhat for clarity. For some e_{ij}* it may be that only data from experts will be considered pertinent and reliable, whereas for e_{ij}' a combination of group estimations and expert estimation is desired. In short, VALUES of various ELEMENTS will be estimated from the different sources because logically certain sources will inherently be more knowledgeable of the characteristics of a particular ELEMENT.

It should be pointed out at this time that the number of individual personnel participating in a VALUE estimation process does not in itself reduce the utility of the factor analysis computational technique (under the assumed conditions of "many units"). There will remain "n" estimates of "L" VALUES. FIGURE AI-2 depicts a matrix of estimates of v_j from the "n" Units Commands of the TYPE being Indexed.

---

†Let $(v_{jk})_i$ represent the VALUE rendered to the j^{th} ELEMENT by the i^{th} expert (or group of experts) in the K^{th} Unit Command; now assume that the importance of this group can be determined, where the importance is denoted α_i. Then an estimate in the V matrix (FIGURE AI-2) is

$$\bar{v}_{jK} = \sum_{i=1}^{N} (v_{jK})_i \alpha_i \quad , \qquad \sum_{i=1}^{N} \alpha_i = 1$$

for N experts (or groups of experts).[2]

$$
\begin{array}{ll|cccccc}
V\ (Lxn) & & \multicolumn{6}{c}{\longleftarrow UC_K^{(T)}\ (K=1\ ,\ldots,n) \longrightarrow} \\
 & & 1 & 2 & . & K & . & n \\
\hline
 & 1 & \bar{v}_{11} & \bar{v}_{12} & . & . & . & \bar{v}_{1n} \\
 & 2 & \bar{v}_{21} & \bar{v}_{22} & & & & \bar{v}_{2n} \\
 & . & . & & & & & . \\
v_j\ (j=1\ ,\ldots,L) & j & . & & & \bar{v}_{jK} & & . \\
 & . & . & & & & & . \\
 & L & \bar{v}_{L1} & \bar{v}_{L2} & . & . & . & \bar{v}_{Ln}
\end{array}
$$

FIGURE AI-2

The figure depicts a matrix of VALUE estimates ($\bar{v}_{jK}$) rendered by the "n" Unit Commands on each of the "L" ELEMENTS. A typical matrix ELEMENT $\bar{v}_{jK}$ may be derived from the following sources:

1. Esimates of v_j by personnel of the K^{th} Unit Command. This is an average of the individual subjective estimates rendered by the individual personnel of that command.

2. Estimates of v_j by a selected group of individuals within the K^{th} Unit Command. This figure is an average of the subjective estimates rendered by the individuals of the group.

3. Estimates of v_j by experts within the K^{th} Unit Command.

4. Lastly, an estimate may be derived from some combination of the sources given in 1-3.

The matrix of VALUE estimates (V) shown in FIGURE AI-2 is the input data for the factor analysis as discussed in Section 2.5 of Chapter III.

Current work is being done in the field of value estimation. The National Aeronautics and Space Administration has experimented with "balloting" techniques for deciding the relative emphasis NASA should put on future programs in space science and space utilization. The technique is called PATTERN--Planning and Evaluation of Relevance Numbers. The scheme was designed by the Honeywell Military Products Group. The present scheme uses a Burroughs 5500 with COBOL as the computer language. Essentially the inputs to the scheme are obtained through voting ("valuation") sessions where "value" decisions are rendered in specific areas by cognitive personnel. The salient feature of the scheme is that participants must defend their ratings and change them if other personnel can reveal convincing information not previously considered; conversely, an individual is not required to bow strictly to consensus.[3]

Before leaving the subject of VALUE determination for the various ELEMENTS we acknowledge that the discussion has not specified the technique to be used for obtaining VALUES in a value-based operational readiness scheme; it has merely outlined the approach. In a specific case, certain techniques (e.g., survey questionnaires versus interviews)† may or may not be available. If VALUE estimation is not feasible for some reason in a specific case, then the Index scheme as outlined here will not be applicable.

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†Regardless of the technique of estimating subjective VALUES, the <u>approach</u> can be made in an objective manner.[4]

APPENDIX I FOOTNOTES

[1]C. West Churchman, Russell L. Ackoff, and E. Leonard Arnoff, Introduction to Operations Research (New York: John Wiley and Sons, Inc., 1957), p. 153.

[2]Ibid., p. 131

[3]William S. Beller, "Technique Ranks Space Objectives," Missiles and Rockets, February 7, 1966, pp. 21-24.

[4]Peter C. Fishburn, Decision and Value Theory (New York: John Wiley and Sons, Inc., 1964), p. 82.

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13. ABSTRACT

A theoretical Unit Operational Readiness Index model is developed after presenting a discussion concerning the implications of military force readiness evaluation. The theoretical model is designed around subject measurement of defined military goals. The quantification of defined goals in the manner proposed suggests the possible use of factor analysis techniques which are discussed. Although the model has not been empirically tested, it endeavors to provide a conceptual visualization of unit operational readiness evaluation and argues for the benefits to be derived from comprehensive schemes of this general type.

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